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Effects of antibiotic and lysine supplementation on growing-fattening pigs fed at different protein levels

Aldon H. Jensen
Iowa State College

EFFECTS OF ANTIBIOTIC AND LYSINE SUPPLEMENTATION ON GROWING-FATTENING PIGS FED AT DIFFERENT PROTEIN LEVELS

by

Aldon H. Jensen

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Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

Head of Major Department

Signature was redacted for privacy.

Dean of Graduate College

Iowa State College

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INTRODUCTION

Protein supplements form an expensive part of the rations fed to growing-fattening pigs. The necessity for protein supplementation to natural feedstuffs is without question, but the quantitative needs of this nutrient for specific phases of growth are not precisely known. Qualitatively and quantitatively the greatest need for proteinacious materials is during the early stages of growth when the increase in body tissues is largely composed of protein.

For many years the incorporation of an animal protein in rations for pigs has proved highly beneficial, especially when the animals were confined to drylot. The animal proteins were complementary to the corn or other cereal grain protein in the ration in regard to the amino acid content, and it was apparent that protein supplements of animal origin were superior to plant protein supplements to a degree greater than could be explained by the amino acid balance alone. Increased growth rates commonly obtained with increased protein content of the rations could be due in part to non-protein dietary factors contained in the animal proteins.

The use of plant proteins, especially soybean oil meal in the corn belt area, has become widely practiced in recent years. This has been due in part to the increasing supply of soybean oil meal and the inadequate quantities of animal protein available.

With the availability of the pure vitamins, especially the recently isolated vitamin B_{12}, their addition to all-plant rations has increased the rate of growth in pigs. This circumstance tends to confirm the opinion that previous practices of increasing the animal protein content of rations had in effect increased non-protein dietary factors which permitted faster growth and more efficient feed utilization. The use of antibiotics and vitamin B_{12} has further complicated the problem of explaining discrepancies in suggested protein requirements of the pig.

It seemed advisable, therefore, to re-evaluate the protein requirements of growing-fattening pigs fed in concrete drylot with and without an antibiotic (aureomycin or terramycin), in terms of optimum levels of protein in corn-soybean oil meal rations. Determining these optimum levels does not, however, indicate the specific need for the intricate components of the protein molecule, the amino acids. Putting the protein needs on an amino acid basis is a valid approach to the defining of a truly balanced ration, insofar as protein is concerned. If the total protein needed in the ration could be lowered by the supplying of adequate non-protein dietary needs, it is conceivable that the amino acid balance of that ration could be improved with the addition of individual amino acids. It has been demonstrated that corn protein can be greatly improved by the addition of lysine and tryptophan, while soybean oil meal is relatively low in methionine. Combining soybean oil meal with corn improves immensely the nutritional balance of these amino acids.

Thus a study of amino acid supplementation to low protein level corn-soybean oil meal rations would be of nutritional interest and economic value.

REVIEW OF LITERATURE

Protein Requirements of Swine

Recognition of the necessity of protein supplementation to corn for economical and efficient gains was early noted. The determination of quantitative requirements, however, has been made only in recent years.

In 1934, Carroll and Garrigus (24) studied 15 and 18 percent protein level rations for pigs from 44 to 200 pounds in drylot. One group was self-fed ground corn, a protein supplement and minerals free choice. The protein supplement consisted of two parts tankage, one part soybean oil meal and one part alfalfa meal, while the mineral mixture was composed of equal amounts of salt, ground limestone and bonemeal. The same ingredients were mixed into complete rations for 15 and 18 percent protein levels. Although the average daily gains throughout the feeding trial were considered very unsatisfactory (ranging from 1.02 to 1.14 pounds per day), there was nothing in the results to indicate that 44-pound pigs fed to market weight required more than 15 percent of protein in the ration.

In 1936, nitrogen-retention studies reported by Mitchell and Hamilton (75) suggested that pigs weighing between 40 and 100 pounds required a ration containing more than 17 percent of crude protein, or 14.4 percent of digestible protein. At heavier weights, for maximum growth a ration containing 15 percent of total protein, or 12 percent of digestible protein, was adequate. Data from Ellis and Hankins (38) reflected these statements, since it was observed that 12, 15, and 19 percent protein levels fed to pigs from 62 to 200 pounds live weight resulted in higher growth rates with increasing protein levels.

Keith and Miller (52,53) fed rations varying in protein content from 12 to 27 percent and found that maximum and most economical gains from weaning to 75 pounds were made by those pigs fed the highest percent of protein. Twenty-two percent was recommended from weaning to 70 pounds, 17 to 20 percent from 75 to 125 pounds and 15 percent from 125 to 200 pounds. A series of studies by Carroll and Burroughs (23) substantiated these conclusions. Mitchell (72), using the same rations as Carroll and Burroughs but employing the nitrogen-retention technique of measuring protein efficiency, stated that 40- to 50-pound pigs required more than 26 percent protein, 100-pound pigs in excess of 17 percent, 150-pound pigs 17 percent and 150- to 200-pound pigs 15 percent protein level rations for maximum growth.

However, Crampton and Ashton (30) proposed 15 to 18 percent protein for pigs from 30 to 100 pounds and 14 to 16 percent for 100 to 200 pounds, while Hanson (42) recommended 18 percent crude protein from 70 to 125 pounds and 13 percent from 125 to 200 pounds. Hillier (44) suggested protein levels of 18, 16, 14, and 12 percent for weight periods of 50 to 80, 80 to 120, 120 to 165 and 165 pounds to market weight, respectively. In 1946, Ferrin (39) demonstrated that a 12 percent protein ration was not sufficient to permit satisfactory growth in weanling pigs. No research dealing with the quantitative protein needs of the pig has been reported since the many B-vitamins, including vitamin B_{12}, and trace minerals have become readily available.

It was desirable, therefore, to study the protein requirements of the pig and the effect of an antibiotic on the protein requirements when corn-soybean oil meal rations were fed.

Nutrient Interrelationships

Satisfactory explanations for discrepancies in the suggested protein requirements of the pig are not readily apparent. Nutritional values of the known vitamins, especially the recently identified vitamin B_{12}, and their possible interrelationships with protein needs must be considered. Increased non-protein dietary factors, namely water-soluble vitamins, may have been responsible for the increased rate of gain obtained when animal proteins were fed.

A close relationship between protein and nicotinic acid was noted by Wintrobe et al. (113). Using semi-purified rations, the omission of nicotinic acid from the diet when a 10 percent protein level was fed resulted in the development of signs of nutritional deficiency. Luecke et al. (59,60) demonstrated how the addition of DL-tryptophan to low protein corn rations prevented nicotinic acid deficiency in the pig and Powick et al. (79) stated that tryptophan appeared to serve as a substitute for nicotinic acid.

From reports of Nelson et al. (77) it was apparent that protein spared pantothenic acid since increasing protein levels from 24 to 64 percent with purified casein diets resulted in greater growth and higher survival.

Sarett and Perlzweig (92) found that the concentrations of riboflavin, nicotinic acid, and thiamin in the rat carcass were not affected by the level of protein in the diet. However, the liver concentrations of riboflavin and nicotinic acid varied directly with the level of protein in the diet.

During a one-week experimental period Sure and Romans (104) observed that with a 7 percent protein diet slight growth could be obtained with high concentrations of the B-complex added, but on low concentrations of the B-vitamins, only maintenance was obtained.

Sarett et al. (91) reported that an increase in protein content of the diet produced a decrease in the urinary excretion of nicotinic acid by dogs and of riboflavin by both dogs and rats. Further, Kleiber and Jukes (54) found that the retention of protein by chicks was decreased when the diet was deficient in riboflavin. Conversely, the urinary excretion of riboflavin by dogs and rats has been shown to bear an inverse relation to the level of protein intake (81). These data are all in agreement in indicating that riboflavin has a profound influence on protein metabolism.

Paired-feeding tests conducted by Spector and Mitchell (101) resulted in the postulation that the interrelationship between nicotinic acid and tryptophan may be analogous to the metabolic interrelationship of choline and methionine. That the amino acid methionine and choline could both serve as methyl donors was shown by Salmon (88). Later work by the same investigator (89) indicated that the utilization of methionine was significantly affected by the protein level of the diet as well as by the presence of vitamin B_{12} in combination with folic acid.

Colby and Trye (29) presented data indicating a definite interrelationship between protein, calcium and magnesium levels in the ration. The feeding of high levels of protein to rats caused a marked growth depression over those fed normal protein rations. A high level of protein increased the severity of a magnesium deficiency, but a combination of the high protein and high calcium was very little more severe than either alone.

Evidence that vitamin B_{12} functions in metabolism of circulating amino acids was reported by Briggs et al., Chow et al., Menge et al., E. L. Oginsky, and Rupp et al. (15,28,66,78,86). That it was involved in transmethylation was reported by Bennett, and Schaefer et al. (10,93). Also, Stern and McGinnis (103) showed that vitamin B_{12}-injected birds were able to more effectively metabolize administered glycine than were the B_{12}-deficient birds.

Vitamin E and vitamin B_{12} could replace each other in promoting protein utilization and in protecting against acute carbon tetrachloride toxicity in young rats reared on 10 percent protein diets deficient in these factors, according to Hove and Hardin (46).

That pyridoxine is intricately involved in protein metabolism has been shown by Lepkovsky and Nielsen (57) who reported the presence of a green pigment-producing compound in the urine of pyridoxine-deficient rats. This substance was later shown to be xanthurenic acid (58), and was noted in excretions of pigs when a similar dietary deficiency existed. Dietary pyridoxine decreased the excretion of free methionine in the urine of rats fed moderate amounts of the amino acid. Dietary methionine did not affect the concentration of vitamin B_6 in the blood or livers of rats (35).

Samuels (90) noticed a decrease in the concentration of ascorbic acid in tissues which metabolize considerable amounts of amino acids, such as the liver, kidneys, and muscle, when a high-protein diet was fed to the rat. Plasma levels of ascorbic acid were also lowered. The author suggested that tissues able to metabolize large amounts of amino acids utilized more ascorbic acid.

Moore et al. (76) reported an apparent decreased susceptibility to the ill effects of a protein-deficient diet when high levels of vitamin A were fed.

Antibiotics and Protein

Swine

The positive response in growth by pigs fed certain antibiotics is an accepted and frequently noted fact.

Although using an APF supplement which was later believed to contain both vitamin B_{12} and an antibiotic, Catron et al. (27) observed as rapid a gain from the APF rations as from rations containing 15 percent meat and bone scraps. The APF ration produced a more uniform rate of gain, a higher average daily gain, a lower feed requirement, and more economical gain.

Burnside et al. (22) showed that APF (Lederle) increased the feeding value of peanut meal and soybean oil meal to the extent that these plant protein supplements were similar in feeding value to the fish meal used.

Using corn-peanut meal rations (fortified with B-complex vitamins, vitamins A and D_2, and minerals) of 19.6, 15.9 and 12.2 percent protein levels, Cunha et al. (31) reported that growth was improved in every case with the addition of APF. Pigs receiving 19.6 and 17.9 percent protein with APF and 19.6 percent protein with APF but not B-complex vitamins demonstrated equal growth. The ration containing APF and 12.2 percent protein equalled the growth obtained from the ration containing 19.6 percent protein without APF.

Cunha et al. (32) reported that methionine supplementation to a corn-peanut meal ration was not beneficial when the ration contained either vitamin B_{12} supplement or APF supplement. The growth response obtained suggested that vitamin B_{12} was a constituent of the APF supplement.

Jukes et al. (51) added an APF supplement to a fortified corn-peanut meal basal ration and the growth responses obtained were comparable to those from rations containing aureomycin.

Vohs et al. (107) fed corn-soybean oil meal rations in drylot and observed significantly faster gains from B_{12}-aureomycin supplement over the gains from crystalline vitamin B_{12} or whey. With B_{12}-aureomycin supplement, improved feed efficiency and the absence of scouring were also observed.

Botkin et al. (13) demonstrated that when an APF supplement containing vitamin B_{12} and aureomycin was added to a plant-protein ration, more efficient gains were produced than when either or both fish meal and tankage supplied the protein.

Poultry

Using natural rations containing soybean oil meal or sunflower seed oil meal, Slinger et al. (99) reported that certain APF concentrates, penicillin, and aureomycin increased the lysine requirement of the poult for normal feather pigmentation. It was also suggested that these materials increased the requirement of this species for other amino acids. The authors suggested that, under the influence of certain APF supplements and antibiotics, the availability of ingested nutrients was increased or an unknown growth factor, or factors, was synthesized in the intestinal tract.

Slinger et al. (98) stated that penicillin or aureomycin did not alter the protein requirement of broilers.

Jones et al. (50) fed practical rations and reported that aureomycin appeared to spare the dietary requirement of tryptophan, but not for lysine.

McGinnis (61) in an experiment on the protein requirement of poults showed that good growth was obtained at lower levels of protein when penicillin was added to the ration. A diet containing approximately 24 percent protein and penicillin gave growth at four weeks of age comparable to that obtained with protein levels as high as 28 percent. When penicillin was not added to the ration, there was a depression in growth at all levels of protein.

It was concluded by Scott et al. (95) that aureomycin did improve growth more at protein levels below the requirement than in the range of the requirement, but that it did not spare dietary protein during the period of growth when the chicks' protein requirement was most exacting. A response to the removal of a supplementary dietary factor (e.g. aureomycin) to a ration could not be regarded as sparing protein *per se* any more than any other nutrient was spared.

Machlin et al. (63) used corn-soybean oil meal diets in three experiments. At four and six weeks of age maximal or near-maximal weight was obtained at the 19 percent protein level with aureomycin. Without the antibiotic, greater weight was attained at 21 or more percent of protein in every case. In all experiments at every protein level, the average weight was greater with aureomycin than without it. Aureomycin improved feed efficiency in each experiment at each level of protein. In general, the higher the protein level, the greater was the increase in feed efficiency induced by aureomycin supplementation.

Similarly, Beily et al. (8) felt that in order to realize the full advantage of the growth-stimulating properties of antibiotics it was necessary to provide a diet of high energy and optimum protein content, as well as one well balanced in amino acids.

According to Almquist (2) systematic investigations, in general, appear to indicate that higher, rather than lower, protein and amino acid levels may be required in association with the stimulation of growth and increase in feed efficiency realized from antibiotic feeding.

Amino Acid Requirements of Growing-fattening Swine

An amino acid is classified as essential when an organism cannot synthesize it from materials commonly supplied, at a rate sufficient to maintain normal growth. In some instances there may be no synthesis at all, and in others the quantity synthesized is so slight that it is considered non-existent. Non-ruminant animals such as the pig, therefore, require a dietary source of the essential amino acids.

Lysine was early shown to be essential for the rat (83), the chick (3), the dog (84), and the young mouse (6). The essentiality of this amino acid to the pig was demonstrated by feeding a purified diet (69). Studies by Brinegar and associates (19) have produced data on the quantitative requirement for weanling pigs. Further study on the essential amino acids was recently reported by Mertz et al. (68).

Dietary requirements of the pig for tryptophan (7,97), methionine (96,33), isoleucine (17), and threonine (67) have been tentatively described.

Data thus far accumulated would suggest that the lysine and methionine requirements of the pig apparently vary with the protein level of the ration.

Amino Acid Supplementation to Pig Rations

Brinegar et al. (18) demonstrated that crude casein plus methionine, a commercial spray-dried whole-blood protein supplemented with methionine and isoleucine, and egg protein were utilized to the same efficiency in nitrogen balance studies. Linseed meal protein plus lysine, histidine, and methionine was less efficiently utilized.

Whitehair et al. (110) obtained a marked growth response when APF, lysine and methionine were added to a corn-soybean oil meal ration.

When adding DL-lysine and DL-tryptophan to high-protein corn supplemented with B-vitamins, minerals, and aureomycin, Ross (85) observed greater gains and feed efficiency than those produced on the high-protein corn alone with B-vitamins, minerals and aureomycin. He also studied the addition of a supplement containing soybean oil meal, blood meal, brewers yeast, fish meal and fish solubles to the high-protein corn ration and reported faster gains, greater daily feed consumption, and less feed per unit of gain than that from the previous test.

Curtin et al. (34) obtained no significant differences in growth rate, feed efficiency, and nitrogen-balance data when DL-methionine was used to supplement a 22 percent protein level ration in which soybean oil meal was the sole source of protein.

However, Dyer et al. (37) obtained significantly faster gains when 0.4 percent DL-lysine was added to a corn-"degossypolized" cottonseed meal ration.

Amino Acid Supplementation to Chick Rations

Richardson et al. (80) found that cottonseed meal supplemented with vitamin B_{12} and L-lysine was equal to soybean oil meal in growth promoting effect.

March et al. (64) using samples of meat meal in which lysine was the primary limiting amino acid, supplemented meat scrap with lysine and obtained a rate of growth almost as rapid as that obtained with fish meal.

Machlin (62) found that chicks fed cottonseed meal grew best when the diet was supplemented with lysine alone. Methionine, glycine, tryptophan, and tyrosine supplementation did not stimulate growth and appeared to depress it.

When rations that were deficient in lysine were fed to poults, the feathers which were developing showed an absence of pigment after approximately two weeks. The level of lysine required to prevent the pigmentation failure increased as the protein level was increased from approximately 10 to 35 percent of the ration.

Early studies on the quantitative amino acid requirements of the chick for optimum growth provided evidence on the level of lysine needed in the diet. Almquist and Mecchi (3), using diets of casein, zein, and edestin found that the best growth was obtained in chicks when the diet contained not less than 0.9 percent L-lysine. Grau et al. (41), using sesame meal as a complete source of amino acids other than lysine, determined the comparative lysine requirement of poults and chicks. It appeared that the lysine requirement of the poult is higher than the chick requirement by an amount which is roughly proportional to the higher protein requirements of poults.

Grau (40) stated that amino acid requirements for chicks may be best expressed in terms of percentages of the diet at a particular protein level, preferably the minimum protein level necessary to promote rapid growth. It was shown that as the protein level was increased, the lysine requirement for maximum growth at a particular protein level increased. This was true whether the lysine requirement was expressed as percentage of the diet, or as the weight of lysine consumed per day per unit of body weight. This same author states that the total lysine requirement with a diet containing 20 percent zein is approximately 1.36 percent. With a practical diet containing cottonseed meal as the only protein supplement and a source of vitamin B_{12}, chicks required a total of one percent L-lysine during the first six weeks for the best growth.

EXPERIMENTAL

Protein Level Studies

Experiment 506

Plan. This first experiment was conducted to re-evaluate the protein requirements of growing-fattening pigs in concrete drylot with and without the antibiotic aureomycin.

The initial protein levels selected for this study were 20, 18, 16, and 14 percent. When the pigs reached an average weight of 75 pounds the protein content of the rations was reduced 3 percentage points to 17, 15, 13, and 11 percent, and at 150 pounds the levels were further reduced to 14, 12, 10, and 8 percent protein. To determine the effect of an antibiotic on the protein requirement of the pig, two of the four lots of pigs on each set of protein levels received ten milligrams of aureomycin hydrochloride per pound of ration. Because of the limitations imposed by litter size, a split-plot design was used so that the effect of different protein levels and the interaction of aureomycin with protein level could be measured as precisely as possible. Each of the two replicates used consisted of two groups of four lots with a random determination as to which group received aureomycin. Within each group of four lots, the four levels of protein were assigned at random. For each group of four lots, eight outcome groups of four pigs were selected. In a few cases where outcome groups could not be made up of littermates, other pigs were selected for uniformity with respect to breeding, previous treatment, weight, condition, and age. One pig from each of the outcome groups was randomly allotted to each lot. The 128 Duroc pigs used had been in continuous drylot with no previous antibiotic treatment. The four groups of four lots were started on experiment within a period of ten days. Average starting lot weights ranged from 29.9 to 37.5 pounds per pig, and the average age ranged from 57 to 59 days. The pigs were wormed with sodium fluoride and sprayed with benzene hexachloride at the beginning of the experiment. Feed and water were available *ad libitum* and the pigs were confined to concrete pens during the entire feeding period. The pigs were weighed individually at two-week intervals and as often as necessary to permit changing protein levels. Each lot of pigs was removed from test at an average weight of approximately 200 pounds per pig.

The ration ingredients are shown in Table 1. The soybean oil meal was a blend of equal parts of three different manufacturers' solvent processed meals. The various protein levels were obtained by adjusting the corn and soybean oil meal content of the ration, based on chemical analysis. The calculated calcium and phosphorus contents of all the rations were held constant by adjusting the amount of steamed bonemeal and calcium carbonate. Table 2 shows the protein content of the rations and the average percent protein consumed by the pigs fed the various rations.

Table 1. Composition of the 20 percent protein basal ration.

	%
Ground yellow corn	63.8
Solvent soybean oil meal (blended)	28.5
Vitamin Premix No. 6[a]	2.0
Vitamin B_{12} Premix[b]	2.0
Special steamed bonemeal	2.5
Calcium carbonate	0.6
Iodized salt	0.5
Trace minerals[c]	0.1
	100.0
Calculated analysis	
Protein	19.95
Fat	2.59
Fiber	3.23
Calcium	1.007
Phosphorus	.602
Vit. A, I.U. per lb.	1576.0
Vit. D_2, U.S.P. units per lb.	400.0
Riboflavin, mg. per lb.	1.71
Niacin, mg. per lb.	19.97
Pantothenic acid, mg. per lb.	8.61
Choline, mg. per lb.	.800

[a]Vitamin Premix No. 6 supplied the following amounts of vitamins per pound of ration:

Vitamin A	300.0 I.U.
Vitamin D_2	400.0 I.U.
Riboflavin	1.0 mg.
Pantothenic acid	2.5 "
Niacin	5.0 "
Pyridoxine	1.5 "
Thiamin	1.5 "
Folic acid	0.5 "
Choline chloride	250.0 "

[b]Vitamin B_{12} Premix contributed 10 mcg. B_{12} per pound of ration.

[c]Contributed the following ppm to the ration: Fe-70, Co-1.6, Cu-4.8, Mn-59, Zn-4.4, and K-76.

Table 1 (Continued)

	Chemical Analysis					
	Protein %		Calcium %		Phosphorus %	
Lot	Calculated	Found	Calculated	Found	Calculated	Found
1	20	20.21	1.01	1.30	0.60	0.73
2	18	18.92	1.07	1.34	0.62	0.76
3	16	16.30	1.03	1.12	0.62	0.68
4	14	14.15	1.01	0.95	0.61	0.63
+ aureomycin						
5	20	20.30	1.01	0.95	0.60	0.64
6	18	18.29	1.07	1.03	0.62	0.65
7	16	16.19	1.03	1.10	0.61	0.70
8	14	14.31	1.01	1.08	0.61	0.63
1	17	17.57	0.98	1.09	0.58	0.65
2	15	14.61	1.05	1.08	0.59	0.63
3	13	13.65	1.01	1.20	0.60	0.68
4	11	11.29	1.00	1.09	0.58	0.64
+ aureomycin						
5	17	17.24	0.98	1.02	0.58	0.61
6	15	15.65	1.18	1.41	0.59	0.63
7	13	13.04	1.01	1.06	0.59	0.64
8	11	11.20	1.00	1.10	0.58	0.64
1	14	15.13	0.93	1.04	0.52	0.61
2	12	12.34	0.98	0.96	0.54	0.55
3	10	10.32	0.94	1.12	0.53	0.51
4	8	8.12	0.94	1.04	0.51	0.56
+ aureomycin						
5	14	15.96	0.93	1.02	0.52	0.59
6	12	12.38	0.98	1.10	0.54	0.60
7	10	10.67	0.94	1.12	0.53	0.61
8	8	8.92	0.94	1.02	0.51	0.57

Table 2. Protein content of rations in percent.

	(As calculated from ingredient analysis)1/			
Initial to 75 lb.	20.1	18.1	16.2	14.2
75 to 150 lb.	17.2	15.2	13.3	11.3
150 to 200 lb.	14.2	12.3	10.2	8.3
	(As found from ration samples)1/			
No aureomycin	20.2	18.9	16.3	14.2
	17.6	15.0	13.6	11.3
	15.2	12.3	10.3	8.1
10 mg. aureomycin per lb. of ration	20.3	18.3	16.2	14.3
	17.2	15.6	13.0	11.2
	16.0	12.4	10.7	8.9
	(Average percent protein consumed)2/			
No aureomycin	16.6	14.7	12.7	10.8
10 mg. aureomycin per lb. of ration	16.6	14.7	12.7	10.8

1/ Analyzed in accordance with official A.O.A.C. methods (1945).

2/ Calculated from the amount of each ration consumed by the 16 pigs on each set of protein levels with and without antibiotic.

Six barrows from each of the four protein-level treatments, including both with and without aureomycin, were slaughtered. Back fat, body depth and total percent of lean in selected cuts were measured.

Statistical analyses. The several groups of data in this test were analyzed statistically. The original data and analyses of variance are shown in the Appendix. Similarly, the original data from Experiments 536, 544, and 553, along with the analyses of variance, are shown in the Appendix. The data from Experiment 527 was not statistically analyzed.

All values reported as significant are at the 5 percent probability level.

Results and discussion. A discussion of the data obtained from this experiment naturally divides itself into four weight periods of the pigs: (1) weaning to 75 pounds, (2) 75 to 150 pounds, (3) 150 to 200 pounds, and (4) weaning to 200 pounds.

Data on daily gain, daily feed, and feed per 100 pounds gain are presented in Tables 3, 4, and 5, respectively, as averages for each of the eight treatments. In Figure 1, the average daily gains of the pigs by treatments from weaning to 200 pounds are shown graphically.

The use of the split-plot design, for the reasons previously stated, severely limits the precision in measuring the effects of the whole plot treatments, antibiotic versus no antibiotic. In this case with only one degree of freedom for error, no attempt will be made to compare statistically the average effect of aureomycin versus no aureomycin. The

Table 3. Summary of average daily gains by weight periods.[1]

	Protein levels (%)				
Initial to 75 lb. 75 to 150 lb. 150 to 200 lb.	20 17 14	18 15 12	16 13 10	14 11 8	Av.
			(Pounds)		
Initial to 75 lb.					
No aureomycin	1.21	1.29	1.26	1.23	1.25
10 mg. aureomycin	1.31	1.28[2]	1.34	1.26	1.30
Average	1.26	1.28	1.30	1.24	
75 to 150 lb.					
No aureomycin	1.53	1.58	1.67	1.64	1.60
10 mg. aureomycin	1.79	1.73[2]	1.83	1.84	1.80
Average	1.66	1.65	1.75	1.74	
150 to 200 lb.					
No aureomycin	1.81	1.81	2.02	1.54[3]	1.80
10 mg. aureomycin	1.94	2.03[2]	1.80	1.88	1.91
Average	1.87	1.92	1.91	1.71	
Initial to 200 lb.					
No aureomycin	1.51	1.55	1.63	1.50[3]	1.55
10 mg. aureomycin	1.68	1.66[2]	1.67	1.66	1.67
Average	1.59	1.61	1.65	1.58	

[1] Each figure (excluding averages) represents an average of two lots of 8 pigs each or a total of 16 pigs.

[2] The gain of one pig which died of a physiological disorder not attributable to nutrition was estimated (Snedecor, 1946).

[3] The gain of one pig was estimated from 150 to 200 lb. (Snedecor, 1946) as it did not respond normally.

Table 4. Summary of average daily feed intake by weight periods.[1/]

	Protein level (%)				
Initial to 75 lb. 75 to 150 lb. 150 to 200 lb.	20 17 14	18 15 12	16 13 10	14 11 8	Av.
			(Pounds)		
Initial to 75 lb.					
No aureomycin	3.44	3.32	3.54	3.23	3.38
10 mg. aureomycin	3.10	3.04	3.50	3.25	3.22
Average	3.27	3.18	3.52	3.24	
75 to 150 lb.					
No aureomycin	6.18	6.34	6.34	6.14	6.25
10 mg. aureomycin	6.50	6.32	6.53	6.66	6.50
Average	6.34	6.33	6.43	6.40	
150 to 200 lb.					
No aureomycin	8.13	8.27	8.65	7.13	8.04
10 mg. aureomycin	8.44	8.69	7.84	8.27	8.31
Average	8.28	8.48	8.24	7.70	
Initial to 200 lb.					
No aureomycin	5.89	5.97	6.06	5.56	5.87
10 mg. aureomycin	5.93	5.83	5.94	5.96	5.91
Average	5.91	5.90	6.00	5.76	

[1/]Each figure (excluding averages) represents an average of two lots of 8 pigs each or a total of 16 pigs.

Table 5. Summary of feed required per hundred pound gain by weight periods.[1]

	Protein level (%)				
Initial to 75 lb. 75 to 150 lb. 150 to 200 lb.	20 17 14	18 15 12	16 13 10	14 11 8	Av.
			(Pounds)		
Initial to 75 lb.					
No aureomycin	285	258	280	261	271
10 mg. aureomycin	238	244	260	257	250
Average	261	251	270	259	
75 to 150 lb.					
No aureomycin	404	401	380	374	390
10 mg. aureomycin	364	376	357	363	365
Average	384	388	368	368	
150 to 200 lb.					
No aureomycin	448	457	428	482	454
10 mg. aureomycin	435	435	435	441	436
Average	441	446	431	461	
Initial to 200 lb.					
No aureomycin	390	383	372	374	380
10 mg. aureomycin	354	360	355	359	357
Average	372	371	363	366	

[1] Each figure (excluding averages) represents an average of two lots of 8 pigs each or a total of 16 pigs.

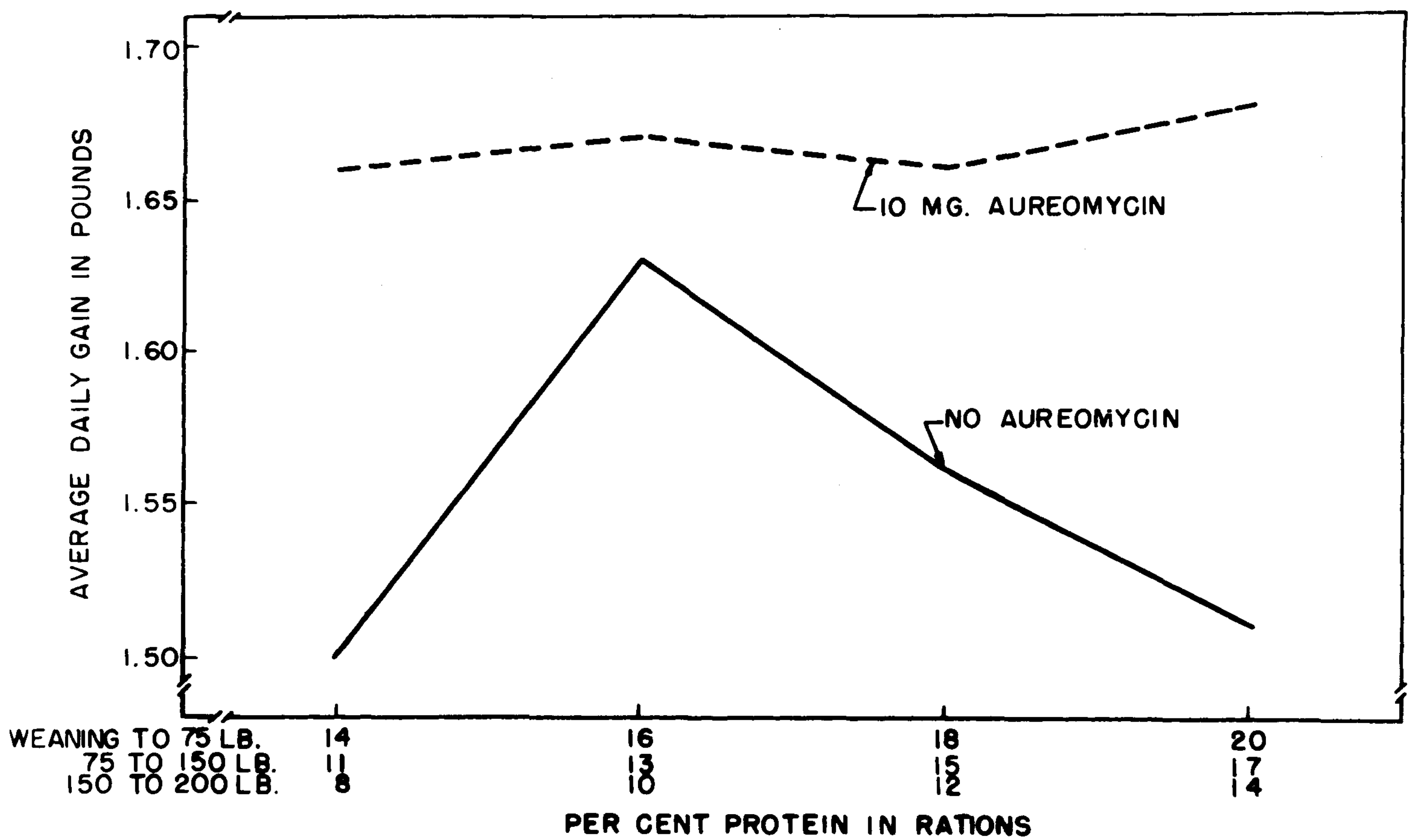


Fig. 1 Mean daily gains of pigs from weaning to 200 pounds on different levels of protein with and without an antibiotic.

discussion will be confined, therefore, to the average effects of protein levels and their interactions with the antibiotic.

Initial to 75 pounds weight. No significant differences in daily gains resulted from varying the protein levels either in the presence or absence of the antibiotic during this period.

The variations in daily feed intake for all treatments considered above were likewise found to be no greater than chance variations.

The data for feed per 100 pounds gain show considerable apparent variability, especially in the absence of the antibiotic. The values for the different protein levels in the presence of the antibiotic were not significantly different but those in the non-antibiotic group were significant. Although the feed efficiency was different on the two treatments, its particular behavior in the absence of the antibiotic is not readily explainable.

There is no evidence in these data to indicate that a protein level higher than 14 percent is superior in any respect for the growth of weanling pigs fed a corn-soybean oil meal ration under the conditions of this experiment.

75 to 150 pounds weight. The average weights of the lots of pigs had a maximum range of only five pounds when the protein levels of the rations were changed. Thus, the average initial weights for this feeding period were relatively uniform.

The average daily gains made by the pigs on the different protein levels in this weight period tend in the opposite direction from those indicated in many previous reports; namely, that the higher percent protein groups would gain more rapidly. While the apparent trend is in favor of the lower protein groups, this trend was found not to be significant. The results indicate that a protein level of 11 percent is adequate for pigs over 75 pounds in weight when fed a corn-soybean oil meal ration either in the presence or absence of the antibiotic at the level fed.

In the case of daily feed intake during this period, a situation similar to that of rate of gain prevailed.

As in the first period, however, there were significant differences in feed per 100 pounds gain during this period. In the case where no antibiotic was fed, there was a steady increase in feed efficiency as the percent protein was lowered. This did not occur in the antibiotic-fed group. There the efficiency was relatively constant for the lots of pigs fed the different protein levels. Continuation of excessively loose feces in the pigs fed higher levels of protein without aureomycin probably caused the accompanying decrease in feed efficiency. This view is partially supported by the fact that no pigs fed aureomycin, even on the higher levels of protein, exhibited this looseness. This, undoubtedly, would account for a portion of the increase in feed efficiency in the aureomycin-fed groups.

<u>150 to 200 pounds weight</u>. The starting weights for this period were but little more variable than those of the previous period as the maximum range between any two treatment averages here was six pounds.

During this period the pigs responded differently on the several protein levels depending upon whether or not they received the antibiotic. When the aureomycin was present in the ration the observed differences in daily gain were found not to be significant. In the absence of the antibiotic, the growth rates differed significantly on the different protein levels.

The daily gain of 1.88 pounds made by the antibiotic 8 percent protein groups compared to 1.54 pounds for the non-antibiotic groups suggests that under conditions of low protein intake the antibiotic exerted a protein "sparing-like" effect.

Feed intake is more variable here than in any period so far considered. The presence of the antibiotic did not, on the average, increase daily feed intake significantly. In its absence, however, feed intakes varied significantly over the range of protein levels. The 8 percent protein group consumed over a pound less feed per day than the other three protein-level groups.

None of the differences in feed per 100 pounds gain were found to be significant.

Initial to 200 pounds weight. Growth response over the entire feeding period showed significant differences among the different protein levels fed depending upon whether or not the antibiotic was present in the ration. The daily gains varied in a parabolic manner in the non-antibiotic groups with the peak of the curve at or near the 16 percent protein level as is shown in Figure 1. When the antibiotic was fed no significant differences in daily gains were observed on the different protein levels. The daily gains as presented in Figure 1 strongly suggest that the feeding of the antibiotic has exerted a "sparing-like" effect on protein. Yet, the average percent protein consumed by the pigs fed with or without antibiotic were the same (Table 2) based on the actual amounts of each ration consumed by the pigs on each set of protein levels with and without antibiotic from weaning to 200 pounds.

The consumption of a ration averaging 12.7 percent protein throughout the feeding period by pigs starting with 16 percent protein is in close agreement with the results of a previous 12-week trial in which the pigs were self-fed, free choice, shelled corn, whole oats, and a well fortified supplement which was highly mineralized to decrease palatability (48). These latter pigs gained 1.50 pounds per day and consumed on the average 11.15 percent of their ration as protein. Their weekly average protein consumption decreased from 12.88 percent to 10.34 percent during the period from weaning to 150 pounds.

No significant differences were found in either daily feed intake or feed efficiency due to ration treatment.

Although the pigs fed aureomycin required 23 pounds less feed to make 100 pounds of gain when compared to those not receiving antibiotic, this difference was not statistically significant. When considered with the report of Catron et al. (26), however, this would appear to be a real saving in feed.

Table 6 shows the summary of protein consumption per pig and the protein consumed per 100 pounds of gain. The protein consumed per pig

Table 6. Summary of protein consumption.

	Protein levels (%)				
Initial to 75 lb.	20	18	16	14	Av.
75 to 150 lb.	17	15	13	11	all
150 to 200 lb.	14	12	10	8	levels
	Average daily protein consumed per pig (Pounds)				
No aureomycin					
36 to 75 lb.	0.69	0.60	0.57	0.46	0.58
75 to 150 lb.	1.06	0.97	0.84	0.69	0.89
150 to 200 lb.	1.16	1.02	0.88	0.59	0.91
36 to 200 lb.	0.98	0.87	0.77	0.60	0.81
10 mg. aureomycin					
30 to 75 lb.	0.62	0.55	0.57	0.46	0.55
75 to 150 lb.	1.12	0.96	0.87	0.75	0.92
150 to 200 lb.	1.20	1.07	0.80	0.69	0.94
30 to 200 lb.	0.98	0.86	0.76	0.64	0.81
	Protein consumed per 100 pounds gain (Pounds)				
No aureomycin					
36 to 75 lb.	57.4	46.8	45.3	37.0	46.6
75 to 150 lb.	69.6	61.1	50.4	42.0	55.8
150 to 200 lb.	63.8	56.3	43.8	40.2	51.0
36 to 200 lb.	64.8	56.2	47.2	40.4	52.1
10 mg. aureomycin					
30 to 75 lb.	47.8	44.2	42.1	36.4	42.6
75 to 150 lb.	62.6	57.3	47.4	39.7	52.0
150 to 200 lb.	61.8	53.6	44.4	36.8	49.2
30 to 200 lb.	58.7	53.0	45.2	38.6	48.9

per day reflects, of course, the total daily feed intake and shows that throughout the feeding period the quantity consumed on each protein level series was very nearly the same in the presence or absence of the antibiotic. That the antibiotic appeared to be sparing protein is evidenced by the fact that with the exception of those pigs receiving 10 percent protein from 150 to 200 pounds the pigs receiving aureomycin made a greater gain per unit of protein consumed. That this phenomenon was not necessarily a function entirely of feed intake is suggested since, where the same quantity of crude protein was consumed daily, the pigs receiving the antibiotic gained more per unit of protein consumed. From initial to 75 pounds in the pigs on the 20 percent protein ration 9.6 fewer pounds of crude protein were needed for 100 pounds of gain when aureomycin was included in the ration. This is not too surprising, however, since the non-antibiotic pigs on this high-protein level exhibited marked looseness the first three weeks of the feeding period. During the period from 150 to 200 pounds there was no evidence of any looseness or other abnormal conditions, yet the pigs receiving 8 percent protein plus the antibiotic required 36.8 pounds of crude protein for each 100 pounds of gain while those on the same ration without aureomycin required 40.2 pounds. During this particular period it should be pointed out that the antibiotic-fed pigs consumed daily .1 pound more of crude protein (1.14 pounds of total ration), perhaps reflecting a stimulated appetite and thus a greater overall consumption of total digestible nutrients, a larger fraction of which would be used for deposition of fat.

That lower protein levels can be fed successfully in balanced rations is supported by recent reports of Hoefer et al. (45), Meade (65), and Terrill et al. (105) showing comparable results obtained with 15 or 14 percent compared to 18 percent protein rations. Bowland et al. (14) reported an apparent sparing effect on protein from the feeding of the antiobiotic penicillin, since pigs on a 13 percent protein ration with antibiotic grew as rapidly as those on a 17 percent protein ration without the antibiotic.

Data presented in Table 7 show no significant differences in backfat measurements between the pigs fed the different levels of protein. Dressing percentage, body length, body depth, and percent lean were not affected by the protein content of the ration nor by the absence or presence of antibiotic, and no analysis was determined. All of these animals, however, were very fat, the average percent of lean in the cross-section of the 24 carcasses at the last rib being only 27.

Fecal samples were collected from representative pigs in groups which received 14 percent protein, with and without antibiotic, and 20 percent protein, with and without antibiotic. There was no apparent correlation in the number of intestinal bacteria and the rate of gain of pigs in this experiment. With the 20 percent level of protein, the addition of antibiotic noticeably increased the total microflora count. When antibiotic was absent, the increase in protein composition of the ration appeared to have little effect on the numbers of enteric microorganisms.

Table 7. Summary of carcass measurements by protein levels and aureomycin treatment.

	No. pigs	Av. Live wt.	Av. Dressing percent	Av.[1] Length of carcass (inches)	Av.[2] Depth of carcass (inches)	Av.[3] Back-fat depth (inches)	Av. Percent lean
Protein Levels (%)							
20 - 17 - 14	6	200	80.1	28.6	13.7	1.80	26.7
18 - 15 - 12	6	197	80.5	28.5	13.1	1.80	24.3
16 - 13 - 10	6	199	81.6	28.5	13.5	1.85	28.8
14 - 11 - 8	6	200	80.5	28.3	13.3	1.85	28.0
No aureomycin	13	201	80.1	28.5	13.4	1.84	27.4[4]
10 mg. aureomycin	11	197	81.5	28.5	13.4	1.83	26.7

1/Length measured from the first rib to the point of the H-bone.

2/Depth measured at the seventh rib.

3/Measurements taken at the first, seventh, last rib and last lumbar.

4/Eleven pigs in this average.

Summary. A total of 128 Duroc pigs were fed a corn-soybean oil meal ration supplemented with minerals and vitamins, including vitamin B_{12} from weaning to 200 pounds in drylot.

A 2X4 factorial experiment in a split-plot design with 0 to 10 milligrams of aureomycin hydrochloride as the whole plots and the initial protein levels of 20, 18, 16, and 14 percent as the sub-plots, was conducted to determine whether previously recommended protein levels are too liberal for present feeding practice and to study the effects of antibiotics supplementation on the protein needs of the pig. Each protein level was reduced three percentage units when the pigs reached 75 pounds and again at 150 pounds.

In the absence of antibiotic, the rate of gain for the entire feeding period varied significantly ($P=0.05$) among the several sets of protein levels. The results suggest that in the absence of an antibiotic the 16-13-10 percent protein level combination supplied the pig's needs for protein from weaning to market, whereas in the presence of the antibiotic the 14-11-8 percent level combination produced gains equivalent to higher levels of protein. Contrary to previous recommendations, higher levels of protein are in excess of the pig's needs if rations are balanced in respect to non-protein dietary factors.

Aureomycin, added to the rate of 10 milligrams per pound of ration, appeared to exert a protein "sparing-like" effect on the lower protein levels.

Pigs receiving antibiotics in their ration gained an average of 0.12 pound more per day and consumed 23 pounds less feed per 100 pounds of gain than those pigs not receiving the antibiotic.

No significant differences existed among the levels of protein fed or between antibiotic and non-antibiotic treatments in respect to back-fat depth, length or depth of body or percent of lean when measured on 24 representative carcasses.

Experiment 527

Plan. If reducing the protein content of the ration did not reduce gains but produced a fatter, less desirable carcass, the practice of feeding higher protein rations would be much the more desirable alternative, if it were economically feasible. Recognizing the fatness of the Duroc breed of hogs from the first experiment it was of immediate interest to learn how a leaner type hog might respond to lower protein level balanced rations. Further, if aureomycin were effectively "sparing" protein, as was indicated especially from 150 to 200 pounds, it was thought that perhaps extremely low protein levels might suffice if the ration were balanced in respect to the other nutrients. Therefore, it was decided to feed corn alone, fortified with minerals including trace minerals and vitamins, as one of the basal rations. In addition, the effect of vitamin B_{12} and/or aureomycin supplementation to different protein levels fed to growing-fattening pigs was studied.

Weanling Landrace X Duroc pigs were selected from all the spring gestation-lactation experiments and were allotted five pigs to a lot on 16 different ration treatments, and confined to concrete floor pens, the latter including inside housing and outside runway. The animals were wormed with NaFl and sprayed with benzene hexachloride at the beginning of the feeding period, and during the experiment feed and water were available *ad libitum*. Weights of the feed and individual pigs were recorded bi-weekly.

Two replicates were started on the experiment, but the data from the second replicate could not be considered because these pigs suffered a streptococcus infection which caused an early termination of that replicate. The first replicate was on experiment for a period of eight weeks.

The rations used were essentially the same as those in the previous experiment except vitamin B_{12} was not included in all the rations. It was desired to feed protein levels of 8, 12, 16, and 20 percent, but the corn used analyzed 8.34 percent protein, with this latter value representing the lowest protein level fed. Blended solvent soybean oil meal was used to increase the protein content of the rations for the 12, 16, and 20 percent levels. Each protein level was fed with and without 10 micrograms of vitamin B_{12} and/or 10 milligrams of aureomycin per pound of ration. The ration ingredients and analysis are shown in Table 8.

Results and discussion. The data in Table 9 show that the leaner type pigs gained as well, and better, on 16 percent protein than on 20 percent protein level rations. This supports the findings in the previous trial in which purebred Duroc pigs were used.

The addition of vitamin B_{12} alone did not consistently increase rate of gain, whereas the antibiotic alone stimulated growth on the three higher levels of protein. With 8 percent protein the average daily gains ranged from 0.22 to 0.41 pounds per day.

Table 8. Composition of 20 and 8 percent protein basal rations.

	20%	8%
Ground yellow corn	63.8	96.0
Solvent soybean oil meal (blended)	30.5	--
Vitamin Premix No. 6[a]	2.0	-- *
Special steamed bonemeal	2.5	3.0
Calcium carbonate	0.6	0.4
Iodized salt	0.5	0.5
Trace minerals[b]	0.1	0.1

*Vitamins added in finely ground corn rather than in soybean oil meal.

Calculated analysis	%
Protein	20.23
Fat	2.59
Fiber	3.23
Calcium	0.987
Phosphorus	0.655
Vit. A, I.U. per lb.	1576.0
Vit. D_2, I.U. per lb.	400.0
Riboflavin, mg. per lb.	1.7
Niacin, mg. per lb.	20.0
Pantothenic acid, mg. per lb.	8.6
Choline, mg. per lb.	800

[a]Vitamin Premix No. 6 supplied the following amounts of vitamins per pound of ration:

Vitamin A	300.0 I.U.
Vitamin D_2	400.0 I.U.
Riboflavin	1.0 mg.
Pantothenic acid	2.5 "
Niacin	5.0 "
Pyridoxine	1.5 "
Thiamin	1.5 "
Folic acid	0.5 "
Choline chloride	250.0 "

[b]Contributed the following ppm to the ration: Fe-70, Co-1.6, Cu-4.8, Mn-59, Zn-4.4, and K-76.

Table 8 (Continued)

	Chemical Analysis					
	Protein %		Calcium %		Phosphorus %	
Lot	Calculated	Found	Calculated	Found	Calculated	Found
1	20.23	21.16	0.99	1.17	0.65	0.70
2	20.23	21.06	0.99	1.11	0.65	0.68
3	20.23	20.65	0.97	1.10	0.65	0.66
4	20.23	20.05	0.99	0.90	0.65	0.59
5	16.04	17.55	1.01	1.02	0.66	0.61
6	16.04	17.86	1.01	1.22	0.66	0.73
7	16.04	17.80	1.01	1.22	0.66	0.74
8	16.04	16.34	1.01	0.97	0.66	0.63
9	11.98	12.69	1.02	1.25	0.59	0.68
10	11.98	12.45	1.02	1.34	0.59	0.70
11	11.98	12.43	1.02	1.18	0.59	0.62
12	11.98	12.04	1.02	1.22	0.59	0.63
13	8.34	8.68	0.97	0.70	0.57	0.47
14	8.34	8.43	0.97	0.98	0.57	0.59
15	8.34	8.67	0.97	0.97	0.57	0.57
16	8.34	8.65	0.97	0.89	0.57	0.56

Table 9. Factors affecting protein requirements of growing-fattening pigs.1/

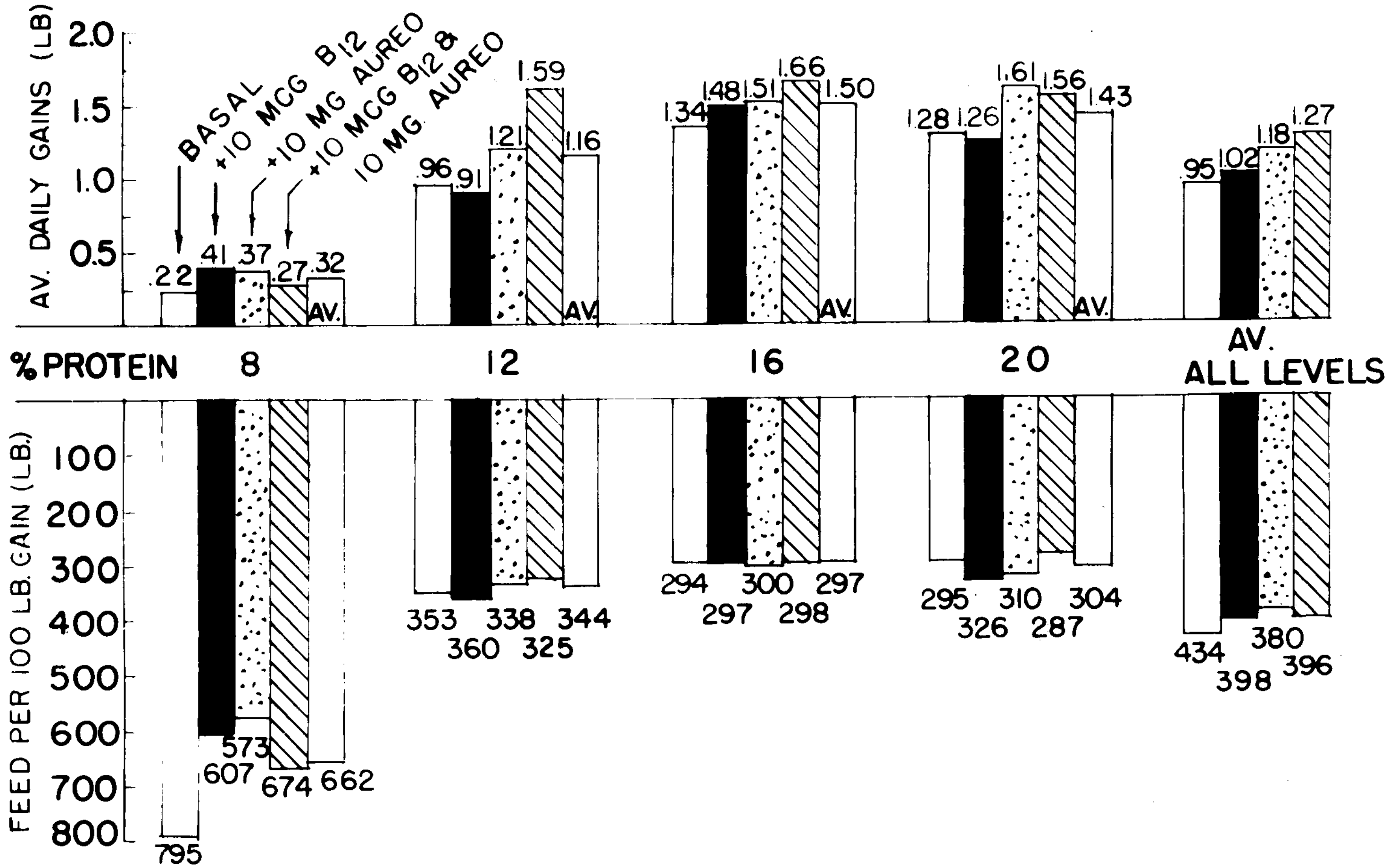
	Av. Initial wt.	Av. Final wt.	Av. Daily gain	Av. Daily feed	Feed per 100 lbs. gain
20% protein	35.8	105.4	1.28	3.76	295
" " + 10 mcg. vit. B_{12}	34.8	103.4	1.26	4.10	326
" " + 10 mg. aureo.	39.8	127.6	1.61	4.98	310
" " + vit. B_{12} + aureo.	35.0	120.2	1.56	4.48	287
Average			1.43	4.33	304
16% protein	36.4	109.4	1.34	3.93	294
" " + 10 mcg. vit. B_{12}	38.2	119.0	1.48	4.40	297
" " + 10 mg. aureo.	36.6	119.2	1.51	4.53	300
" " + vit. B_{12} + aureo.	34.4	124.8	1.66	4.93	298
Average			1.50	4.45	297
12% protein	35.0	87.2	0.96	3.38	353
" " + 10 mcg. vit. B_{12}	35.4	85.0	0.91	3.28	360
" " + 10 mg. aureo.	38.4	104.2	1.21	4.08	338
" " + vit. B_{12} + aureo.	41.0	128.0	1.59	5.17	325
Average			1.16	3.98	344
8% protein	38.0	49.8	0.22	1.72	795
" " + 10 mcg. vit. B_{12}	35.6	57.8	0.41	2.47	607
" " + 10 mg. aureo.	39.8	60.2	0.37	2.14	573
" " + vit. B_{12} + aureo.	36.8	51.6	0.27	1.83	674
Average			0.32	2.04	662
<u>Av. all protein levels</u>					
Basal			0.95	3.20	434
10 mcg. vit. B_{12}			1.02	3.56	398
10 mg. aureomycin			1.18	3.93	380
Vit. B_{12} + aureomycin			1.27	4.10	396

1/Five pigs per lot.

Growth rates and feed required for each 100 pounds of gain on the different protein levels are graphically shown in Figure 2. It is evident that the least variation in growth rate response occurred with those rations containing 16 percent protein. The average daily gains obtained on the different protein level treatments demonstrate very strikingly the nutritional inadequacy of the corn alone even when fortified with vitamins including vitamin B_{12}, minerals including trace minerals, and the antibiotic aureomycin.

That the 8 percent protein ration was unpalatable was shown by the fact that the average daily feed consumption over the eight-week period was only 2.04 pounds (Table 9), the greater proportion of which would of necessity be used for maintenance. On this lower protein level the pigs continuously rooted and kicked feed out of the self-feeder, as if searching for something more to their liking. This is in contrast to the previous experiment during the period from 150 to 200 pounds live weight when a similar ration was quite readily consumed and produced a very satisfactory growth rate.

Feed efficiency was highest on the 16 percent protein level rations, and lowest when the 8 percent rations were fed. A marked improvement in daily gain, feed consumption and feed efficiency resulted from the addition of enough soybean oil meal to the corn ration to provide 12 percent protein. The addition of ten pounds of soybean oil meal to 90 pounds of the corn ration increasing the protein level from 8 to 12 percent increased gains 262 percent and feed efficiency 92 percent. Although an unidentified factor(s) in the soybean oil meal may be



1. FIVE PIGS PER LOT (TOTAL 80 PIG)
2. ALL-PLANT PROTEIN BASAL INCL. MINERALS T.M & VITS.

Fig. 2 Daily gains and feed per 100 pounds of gain for pigs receiving different protein levels with and without vitamin B_{12} and/or aureomycin.

involved, it would appear that the marked response was due primarily to the improved amino acid balance and quantity. The soybean oil meal protein is an excellent supplement to the corn protein which is deficient in lysine and tryptophan, thus providing a much better balance of amino acids in the ration.

In the absence of the antibiotic and vitamin B_{12} the 16 and 20 percent protein rations produced faster gains and were more efficiently utilized. The addition of vitamin B_{12} alone produced in the animals a looseness which was not evidenced in the absence of the vitamin, and was completely absent when the antibiotic was fed. This would support earlier work which suggested that a reduction of a scouring condition was attributable to the antibiotic, thus permitting more efficient utilization of the feed and more rapid growth (47).

Summary. Eighty Landrace x Duroc pigs were fed, from a beginning average weight of approximately 37 pounds, for eight weeks. Eight, 12, 16, and 20 percent protein level corn-soybean oil meal rations were fed, with and without vitamin B_{12} and in the presence or absence of aureomycin.

Considering all treatments, 16 percent protein in the ration resulted in most rapid gain and best feed efficiency.

Corn alone fortified with vitamins including vitamin B_{12}, minerals, trace minerals and an antibiotic, was clearly quantitatively and qualitatively inadequate for optimum growth.

Experiment 536

Plan. In view of the results of the first two experiments, it was deemed desirable to continue the study of the quantitative protein requirement of the pig from weaning to market weight when fed in drylot. In addition to the antibiotic aureomycin, terramycin was also used. Further, additional data were needed to determine what effects the antibiotics and different protein levels may have on the quality of the carcass produced.

This test differed from the first experiment in that 10, 12, 14, 16, 18, and 20 percent protein levels were fed continuously from weaning to 200 pounds live weight. Feeding only one level of protein throughout the feeding period would not only provide important nutritional information but, in addition, a replacement value of corn-soybean oil meal could be determined and a chart devised to relate the economic patterns to method of feeding. The 20 percent protein level ration and analysis of the rations are shown in Table 10.

One hundred and ninety-two Duroc and Poland China X Landrace X Duroc weanling pigs from similar previous treatments were randomly allotted to the different treatments within each replicate.

On each protein level, three lots of pigs received no antibiotic, three lots received 5 milligrams of aureomycin per pound of ration, and two lots received 5 milligrams of terramycin per pound of complete ration. The first replicate contained three crossbred pigs and one Duroc pig per pen, the second replicate had four crossbred pigs and in the third replicate three Duroc pigs and one crossbred pig were in each

Table 10. Composition of the 20 percent protein basal ration.

	%
Ground yellow corn	61.0
Solvent soybean oil meal (blended)	32.0
Vitamin Premix No. 19[a]	2.0
Vitamin B_{12} Premix[b]	1.0
Special steamed bonemeal	2.8
Calcium carbonate	0.6
Iodized salt	0.5
Trace minerals[c]	0.1
Calculated analysis	
Protein	20.09
Fat	2.49
Fiber	3.32
Calcium	1.06
Phosphorus	0.72
Vit. A, I.U. per lb.	2020.0
Vit. D_2, I.U. per lb.	400.0
Riboflavin, mg. per lb.	1.52
Niacin, mg. per lb.	20.08
Pantothenic acid, mg. per lb.	5.23
Choline, mg. per lb.	577

[a]Vitamin Premix No. 19 supplied the following amounts of vitamins per pound of ration:

Vitamin A	786.0 I.U.
Vitamin D_2	406.0 I.U.
Riboflavin	0.78 mg.
Pantothenic acid	1.58 "
Niacin	10.12 "
Pyridoxine	1.02 "
Thiamin	1.02 "
Folic acid	0.56 "

[b]Vitamin B_{12} Premix supplied 5 mcg. per pound of ration.

[c]Contributed the following ppm to the ration: Fe-70, Co-1.6, Cu-4.8, Mn-59, Zn-4.4, and K-76.

Table 10 (Continued)

Chemical Analysis					
Protein %		Calcium %		Phosphorus %	
Calculated	Found	Calculated	Found	Calculated	Found
10.08	9.85	0.99	1.18	0.63	0.70
11.93	12.31	1.00	1.21	0.65	0.72
14.16	14.34	1.01	1.16	0.67	0.71
16.02	15.88	1.02	1.05	0.70	0.67
18.05	17.31	1.05	1.15	0.69	0.70
20.09	19.97	1.06	1.20	0.72	0.72

lot. The crossbred pigs were from Poland China boars and out of Landrace X Duroc sows. Initial weights of the pigs on experiment were approximately 35 pounds.

The corn-soybean oil meal rations were basically the same as those in the previous two experiments, with the different protein levels obtained by varying the proportion of soybean oil meal to corn. Three different vitamin premixes were used, as shown in Table 11, one each for the 10 and 12, 14 and 16, and 18 and 20 percent protein level rations, respectively, in an effort to equalize the vitamin content of all the rations fed. Feed and water were available <u>ad libitum</u>. Feed weight, by lots, and the weight of the individual pigs were recorded every two weeks. Each pig was removed from experiment at approximately 200 pounds live-weight.

It was planned to take two barrows from each lot, at 200 pounds, for slaughter, but due to a dermatitis condition arising during the course of the experiment, only one barrow per lot was slaughtered, except in the 20 percent protein level lots from which none were slaughtered. From those animals slaughtered, records were taken of back-fat depth (both live probe and carcass measure), length of carcass, percent of lean cuts, weight of leaf fat, area of loin muscle, and specific gravity. These measures were taken in an effort to establish the degree to which the carcass produced may have been affected by the antibiotic and/or protein levels fed.

Table 11. Premixes for Experiment 536.

Ingredient added	10 & 12% Protein rations		14 & 16% Protein rations		18 & 20% Protein rations	
	Quantity	Contains per lb. of premix	Quantity	Contains per lb. of premix	Quantity	Contains per lb. of premix
Choline (25%)	11.0 lb.	12.485 gr.	4.5 lb.	5.40 gr.	--	--
Folic acid	2.5 gr.	25.00 mg.	2.37 gr.	25.00 mg.	2.22 gr.	25.00 mg.
Niacin	50.0 "	500.00 "	47.50 "	500.00 "	44.50 "	500.00 "
Calcium pantothenate	13.0 "	130.00 "	9.45 "	100.00 "	16.67 "	75.00 "
Pyridoxine	5.0 "	50.00 "	4.75 "	50.00 "	4.45 "	50.00 "
Riboflavin	5.0 "	50.00 "	4.27 "	45.00 "	3.56 "	40.00 "
Thiamin	5.0 "	50.00 "	4.75 "	50.00 "	4.45 "	50.00 "
Vitamin A (crystalline)	3.0 "	30.00 "	5.50 "	58.00 "	7.12 "	80.00 "
Vitamin D (142-F)	14.2 "	142.00 "	13.49 "	142.00 "	12.64 "	142.00 "
Soybean oil meal (solvent)	88.7 lb.		88.7 lb.		88.70 lb.	
Total	100.0 lb.		94.5 lb.		89.00 lb.	

<u>Results and discussion</u>. During the course of this experiment an abnormal skin condition developed which appeared to be of equal intensity in the different treatments. First evident symptoms were welts arising on the belly, which resembled a ringworm-infection. An oily, scaly condition would soon be observed on the ears. The skin disturbance progressed from the belly up the sides of the body but did not seem to affect the dorsal covering. The area of the hams and legs were often completely covered with a crusty, scaly layer, and in the most advanced cases the moving of the hind quarters appeared to be awkward or painful to the pig. The intensity of the development of the skin condition varied markedly with individual animals. Slight manifestation could exist with no apparent growth inhibition. Development to an extreme degree of aggravation could result in temporary or prolonged growth stasis or loss of weight. Although a few animals exhibited this skin abnormality at about 50 pounds live weight, most of those affected were between 75 and 150 pounds. Nearly spontaneous recovery was observed in several of the pigs, but in others the condition became static, slowly became more severe, or very gradually improved. The exact etiological agent could not be definitely defined by the veterinary clinicians. No treatments employed were completely satisfactory. The autopsy report of one animal sent to the veterinary diagnostic laboratory was as follows:

Re: Our Case No. 3662. "Examination of pig # 767S out of experiment # 536, received 28 December, revealed the presence of a severe and extensive exfoliative dermatitis with a minimum amount of exudation or suppuration, but with encrustation present and involving all the underside and the neck, face, head and ears. All the superficial lymph glands draining the affected parts exhibited a marked adenitis. The visceral lymph glands were identical but not so marked. The lungs were shrunken and fibrotic. There was a marked anemia. There was a mucoid and a slight catarrhal gastritis and a duodenitis and jejunitis. The food passing through the digestive tract was in a very incomplete state of digestion. Cecal contents contained many Balantidium coli protozoa and large bacteria. The liver and kidneys were soft and friable, and the spleen was pale.

Bacteriological cultures made of the vital organs and also the affected tissues and structures failed to yield any significant cultures of pathogenic organisms.

In consideration of the history, autopsy findings and laboratory determinations, it is my opinion that the anemia and exfoliative dermatitis existing in this specimen is not infectious disease in nature."

Signed: Loyd D. Jones
Iowa Vet. Diag. Lab.

Only the data from the first two replicates were used in the calculations and analysis of data. This procedure was followed in order to compare the two antibiotics. When lot averages were calculated for the respective treatments, however, there were no appreciable differences between the first two replicates or among all three replicates.

Although the same protein levels were fed throughout the experiment, the early growing period from 35 to approximately 75 pounds live weight, during which the protein requirements are believed to be most exacting, was considered separately. Further, the deleterious effect of the dermatitis was believed to be negligible during this period.

Average daily gains and feed required per 100 pounds of gain are shown in Table 12. During the early phase of growth the peak rate of gain in the absence of the antibiotic was 1.37 pounds per day on the 14 percent protein level. With aureomycin and terramycin in the rations peak growth rates of 1.41 and 1.52 pounds per day were obtained on the 16 and 14 percent protein level rations, respectively.

The average daily gain during this period on all protein levels with terramycin was significantly greater than those without the antibiotic, but this advantage disappeared by the time the animals reached 200 pounds live weight.

Between the different protein levels fed there was a significant increase in daily gain with increasing protein level fed up to 14 percent, with slightly reduced growth rate on the higher levels of protein fed.

There were wide variations in apparent feed utilization. There are no consistent trends to show a specific effect of protein level. Considering the average amount of feed required for each 100 pounds of gain, the pigs receiving either antibiotic appeared to utilize their feed more efficiently than those animals not receiving an antibiotic. It is the opinion of the author, however, that the variation in initial weights of the animals and the short time period required to reach

Table 12. Effect of antibiotics on protein requirements of growing-fattening swine.

Protein level	10	12	14	16	18	20	Av.
			Weaning to 75 pounds				
			Average daily gain (pounds)				
No antibiotic	1.02	1.11	1.37	1.32	1.33	1.26	1.23
Aureomycin	1.01	1.35	1.33	1.41	1.28	1.34	1.30
Terramycin	1.15	1.31	1.52	1.33	1.42	1.53	1.38
Average	1.06	1.26	1.41	1.35	1.34	1.38	
			Feed per 100 pounds gain				
No antibiotic	349	314	309	383	343	297	332
Aureomycin	329	312	309	277	321	321	311
Terramycin	301	327	267	346	365	295	317
Average	326	317	295	335	343	304	
			Weaning to 200 pounds				
			Average daily gain (pounds)				
No antibiotic	1.44	1.56	1.60	1.64	1.67	1.62	1.59
Aureomycin	1.43	1.63	1.73	1.69	1.59	1.60	1.61
Terramycin	1.52	1.68	1.77	1.57	1.66	1.61	1.63
Average	1.46	1.62	1.70	1.63	1.64	1.61	
			Feed per 100 pounds gain				
No antibiotic	390	355	421	370	383	386	384
Aureomycin	393	361	339	350	376	360	363
Terramycin	392	363	356	375	382	379	375
Average	392	360	372	365	380	375	

average lot weights of approximately 75 pounds preclude fair evaluation of the relative efficiencies of the different rations fed during this period.

Considering the average gains of the non-antibiotic-fed pigs from weaning to 200 pounds there was an increase from 1.44 pounds per day on the 10 percent protein level to 1.67 pounds per day on the 18 percent protein level. The most marked increase is evidenced between the 10 and 12 percent protein levels with a very slight, gradual increase increment with higher protein levels up to 18 percent, then a slight drop on the 20 percent protein level. With aureomycin or terramycin at 5 milligrams per pound of total ration the peak in growth rate occurred on the 14 percent protein rations, with less rapid growth resulting from the higher protein levels.

In Figure 3 are shown the smoothed curves which connect the points representing the average daily gains made on the different treatments from weaning to 200 pounds live weight. In the absence of the antibiotics the peak gain occurred on the 18 percent protein level. With terramycin or aureomycin included in the rations the most rapid gains were produced by the 14 and 16 percent protein levels, respectively. This reflects the relative response on the different protein levels during the early growing period.

Considering all the protein levels fed, there were no significant differences in average daily gain obtained between non-antibiotic and antibiotic supplementation. Between protein levels, however, there was a statistically significant trend with increasing protein levels. Those

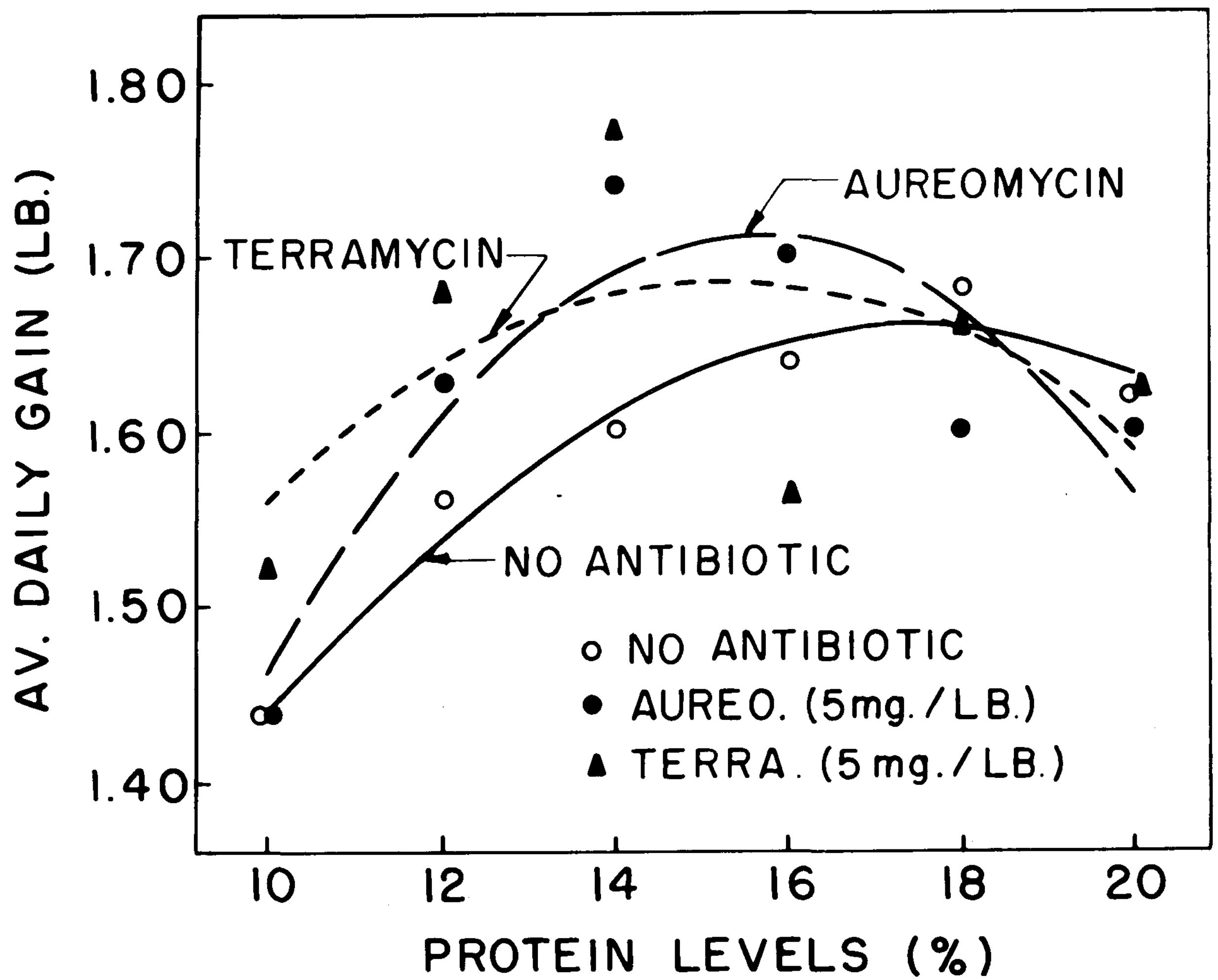


Fig. 3 Response of growing-fattening pigs on different protein levels with and without an antibiotic.

pigs receiving 16 percent protein level rations gained most rapidly, while slower growth rates were obtained from higher protein levels.

In all instances, the 10 percent protein level rations were inadequate, apparently both qualitatively and quantitatively, for maximum growth response.

The amount of feed required for each 100 pounds increase in body weight from the respective treatments shows that with the exception of the 10 percent protein level rations, there are extreme and inconsistent variations during the period from weaning to 200 pounds. The data indicate that in the absence of an antibiotic the 12 percent protein level ration was utilized most efficiently, while with aureomycin and terramycin present, the most efficient utilization was realized on the 14 percent protein level rations. This wide divergence of trend was wholly unsupporting of the previous experimental work and other investigational data. It could be explained in part by the unnatural behavior resulting from the dermatitis manifestation. In addition, however, an important contribution was made by presumed inaccuracy of feed records resulting from inability to completely control the feed-wasting tendencies of certain lots of pigs, this wastage showing no reflection of any particular ration. No statistical analysis of these feed data was attempted.

Considering all the treatments, approximately 20 pounds less feed were required for each 100 pounds of gain when aureomycin was included in the rations and approximately 10 pounds less feed were required when terramycin was fed.

The average values show that the pigs on the 10 percent protein levels required the greatest quantity of feed for each unit of gain.

A similar experiment using these same levels of protein was conducted in which aureomycin was the only antibiotic used (1). The data obtained showed that in the absence of an antibiotic, the 16 percent level of protein in the ration produced the most rapid gains, while with 5 milligrams of aureomycin in the rations 14 percent protein produced the greatest gains. With the antibiotic, the 12 percent protein levels produced gains equal to or greater than the 16, 18, and 20 percent protein levels. Feed efficiency data suggested that 14 and 16 percent protein level rations were most efficient in the absence of an antibiotic, while 12 percent was most efficient when aureomycin was included in the ration. Ten percent protein level rations were again inefficient, and were apparently inadequate for optimum growth and feed efficiency.

Slaughter data. Thirty barrows were selected for slaughter and were taken from the experiment at individual weights of approximately 200 pounds.

Immediately preceding slaughter, back-fat measurements of the live animal were taken according to the procedure of Hazel and Kline (43). After slaughter and chilling of the carcass, the following measurements were recorded: back-fat thickness, carcass length, specific gravity, area of the loin muscle, percent lean cuts, and weight of leaf fat.

Considering the average values of each measurement, there was no indication that the inclusion of an antibiotic in the ration fed affected adversely the quality of the carcass produced.

Further, no single measurement, such as back-fat thickness, was a safe indication of the degree of fatness indicated by the other measurements taken.

Considering the different protein levels fed, the specific gravity and percent lean cuts were the only measurements showing an effect on carcass quality of the level of protein in the ration fed.

Table 13 shows a summary of the carcass data. If specific gravity were used as the single criterion of degree of fatness, it would appear that the carcasses from the animals receiving 10 percent protein level rations contained the most fat. The data show a significant trend in specific gravity values, 1.0204 to 1.0321, from the low-protein level up to the 16 percent protein level rations, and then indicate a slight drop on the 18 percent protein level. This consistent increase in values demonstrates that a leaner carcass was being produced in those animals which had received the higher protein levels. That specific gravity is highly indicative of fat and lean content of a carcass has been shown by Brown et al. (20) and Whiteman et al. (111).

Calculation of the percent of the chilled carcass represented by the trimmed cuts of ham, belly, picnic, loin, and Boston butt, reflects the trend shown by the specific gravity values. The percent lean cuts increased with higher protein levels fed up to 16 percent, then dropped

Table 13. Summary of carcass data.

Protein levels (%)	10	12	14	16	18	Av.
			Back-fat depth (inches)			
No antibiotic	1.65	1.47	1.63	1.44	1.59	1.56
Aureomycin (5 mg/lb.)	1.66	1.45	1.50	1.49	1.41	1.50
Terramycin (5 mg/lb.)	1.58	1.62	1.66	1.42	1.62	1.58
Average	1.63	1.51	1.60	1.45	1.54	
			Leaf fat in pounds			
No antibiotic	4.5	5.0	4.6	4.9	4.3	4.7
Aureomycin (5 mg/lb.)	4.4	4.2	4.4	4.3	3.4	4.1
Terramycin (5 mg/lb.)	4.8	4.8	3.4	4.2	3.5	4.1
Average	4.6	4.7	4.1	4.5	3.7	
			Percent lean cuts			
No antibiotic	57.0	59.0	60.8	58.5	60.5	59.2
Aureomycin (5 mg/lb.)	57.8	59.2	60.8	61.2	59.2	59.6
Terramycin (5 mg/lb.)	60.0	56.6	57.6	63.0	57.2	58.9
Average	58.3	58.3	59.7	60.9	59.0	
			Specific gravity			
No antibiotic	1.0167	1.0249	1.0244	1.0302	1.0281	1.0249
Aureomycin (5 mg/lb.)	1.0201	1.0272	1.0244	1.0293	1.0305	1.0263
Terramycin (5 mg/lb.)	1.0245	1.0242	1.0281	1.0368	1.0249	1.0277
Average	1.0204	1.0254	1.0256	1.0321	1.0278	
			Carcass length (inches)			
No antibiotic	27.8	28.7	28.5	29.2	28.7	28.6
Aureomycin (5 mg/lb.)	28.6	28.9	28.9	28.9	29.1	28.9
Terramycin (5 mg/lb.)	29.1	28.9	29.4	29.5	28.5	29.1
Average	28.5	28.8	28.9	29.2	28.8	

Table 13 (Continued)

Protein levels (%)	10	12	14	16	18	Av.
			Live probe (inches)			
No antibiotic	1.68	1.40	1.52	1.41	1.48	1.50
Aureomycin (5 mg/lb.)	1.46	1.45	1.53	1.46	1.44	1.47
Terramycin (5 mg/lb.)	1.49	1.62	1.62	1.47	1.69	1.58
Average	1.54	1.49	1.56	1.44	1.54	
			Area of loin muscle (traced) (square inches)			
No antibiotic	3.8	4.4	4.3	4.1	4.3	4.2
Aureomycin (5 mg/lb.)	3.8	4.0	3.7	3.7	3.2	3.7
Terramycin (5 mg/lb.)	4.1	3.6	3.9	4.5	4.1	4.0
Average	3.9	4.0	4.0	4.1	3.9	

slightly at the 18 percent protein level. This trend, however, was not statistically significant, but indicated an inverse relationship between the fat content of the carcass and the level of protein fed.

Although the carcasses from the pigs fed 18 percent protein contained the least leaf fat, there were no significant differences among the protein levels fed. The data do suggest that the animals which received no antibiotics laid down more leaf fat than did the pigs consuming the same rations fortified with aureomycin or terramycin.

In Figure 4 the average values of four measurements are graphically illustrated showing the apparent increasing percent of lean tissue and decreasing percent of fat with increased protein levels.

The complete absence of any deleterious effect on the carcass produced due to the feeding of antibiotics is supported by Wilson et al. (112). With recommended and low levels of protein, an antibiotic, alone and with vitamin B_{12}, stimulated growth and also improved the quality of the resulting carcasses.

Robison et al. (82), however, reported on various factors which influence the yields of pork cuts and stated that carcasses from hogs on rations containing a B_{12} and antibiotic supplement contained 49.9 percent of lean cuts, while hogs fed rations without the B_{12} antibiotic supplement produced carcasses containing 51.6 percent lean cuts. He also stated that percent of lean cuts reflected the protein levels fed, the values increasing in carcasses from hogs fed 10, 12, 15, and 20 percent protein

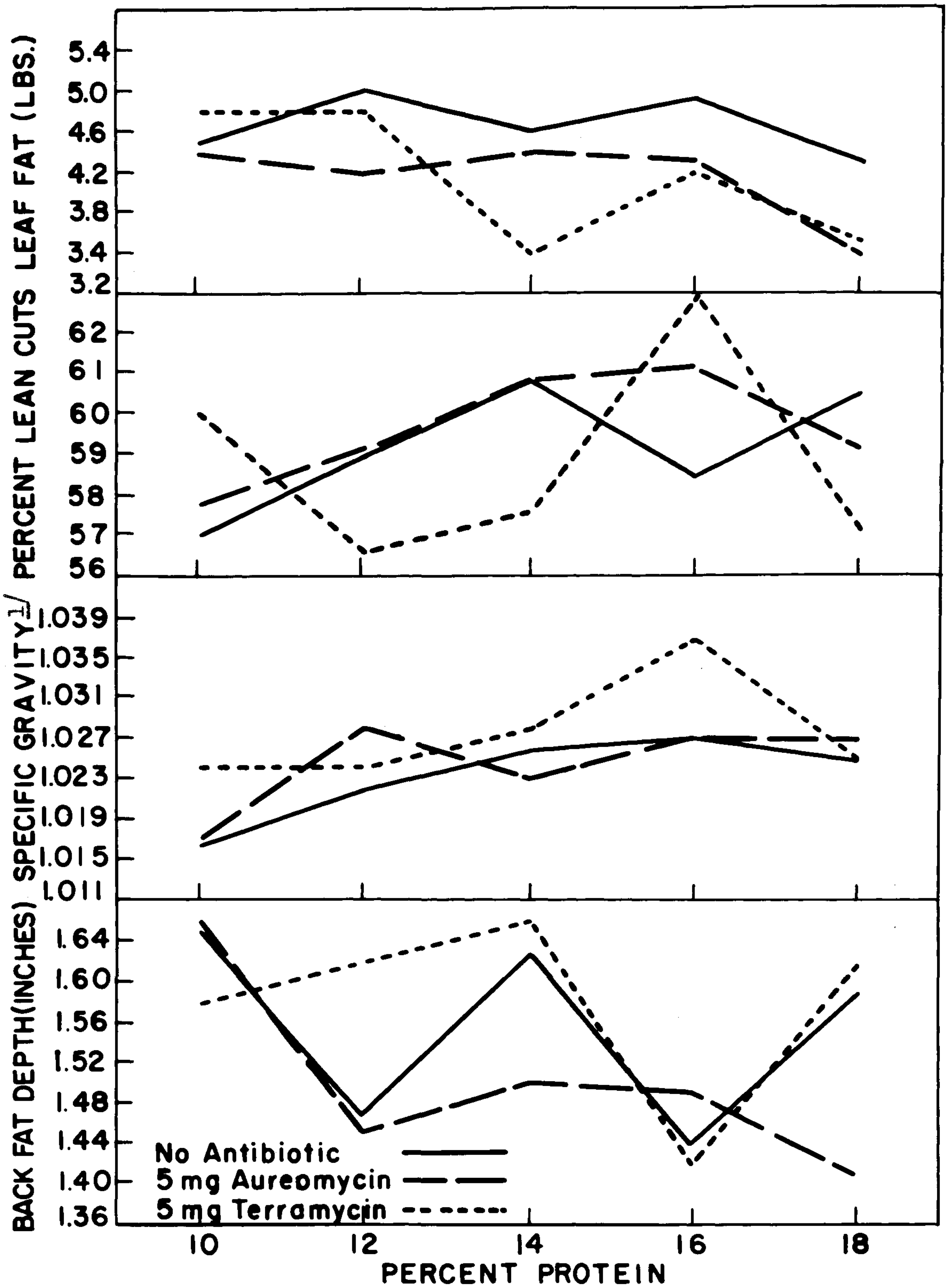


Fig. 4 Average data from four carcass measurements.
1/Total of 40 carcasses represented.

levels, respectively. Similar findings on effect of protein level fed were reported earlier by the United States Department of Agriculture (106) and by Ellis and Hankins (38).

<u>Summary</u>. Under the conditions of this experiment a 12 or 14 percent protein balanced ration, including either aureomycin or terramycin, proved adequate for pigs from weaning to 200 pounds in drylot. Higher levels of protein were in excess of the pig's needs for satisfactory growth and feed efficiency.

In the absence of an antibiotic, the 16 percent protein ration appeared to be more satisfactory than did the 14 percent ration. A 10 percent protein-level, corn-soybean oil meal ration, with or without an antibiotic, was inadequate for the pig's needs.

Carcasses from pigs receiving antibiotics did not differ in fat content from those pigs which received no antibiotic.

As measured by specific gravity and percent of lean cuts, the fat content of the carcasses tended to decrease with increased protein levels fed.

Lysine Supplementation Studies

From the results of the first group-feeding experiment, it appeared that aureomycin was exerting a protein-sparing effect, especially during the period of growth from 150 to 200 pounds with those pigs receiving corn alone supplemented with vitamins and minerals including trace minerals. In an effort to narrow the effects to a specific amino acid, the methionine, tryptophan, cystine, and lysine contents of the different rations were calculated using average analysis values reported by Block and Bolling (11).

The requirement for the amino acid lysine appears to be in proportion to the level of protein fed. Steffe et al. (102) demonstrated a proportional relationship of amino acid requirements in studies with rats. Brinegar et al. (19) provided sound evidence that with growing-fattening pigs a diet containing 10.6 percent protein and 0.6 percent lysine gave better growth rate than did lower levels, and as good growth as did higher levels of the amino acid with the same protein level. During this same feeding trial 1.2 percent lysine gave optimum growth when the diet contained 22 percent protein. Proportionately, therefore, the lysine requirement of swine may be considered as 5.5 percent of the dietary protein (16).

Based on this theory that the amino acid requirement is in proportion to the protein content of the ration, the calculated requirements of the four amino acids methionine, tryptophan, cystine and lysine are shown in Table 14. In addition the microbiologically-assayed values of the lysine and methionine contents of the 8, 10, 11, 12 and 14 percent protein level rations used in Experiment 506 are presented.

These data indicate that lysine was the primary limiting amino acid when the all-corn ration (8 percent protein) was fed. Whereas the calculated lysine content of the corn was 0.18 percent, microbiological assay indicated a content of 0.28 percent. Both of these quantities are considerably lower than the theoretical calculated requirement of 0.46

Table 14. Amino acid content of rations (reported as percent of the total ration).

Approx. Protein Content	Lysine			Methionine			Tryptophan		Cystine
	Calc.1/	Found2/	Req.3/	Calc.1/	Found2/	Req.4/	Calc.1/	Req.5/	Calc.1/
20	1.11		1.11	0.41		0.58	0.24	0.16	0.35
14	0.65	0.72	0.78	0.33	0.32	0.41	0.14	0.11	0.24
18	0.95		1.00	0.38		0.52	0.20	0.14	0.31
12	0.50	0.60	0.68	0.30	0.29	0.35	0.11	0.10	0.20
16	0.79		0.89	0.35		0.46	0.17	0.13	0.27
10	0.33	0.45	0.56	0.27	0.25	0.29	0.08	0.08	0.16
11	0.41	0.48	0.62	0.29	0.28	0.32	0.09	0.09	0.18
8	0.18	0.28	0.46	0.25	0.21	0.24	0.05	0.07	0.12

1/Calculations based on values of Block and Bolling (1951).

2/Amino acid assays by a method of Kuikon et al. (1943) and Dunn et al. (1947).

3/Based on 1.2 percent L-lysine required in a 22.0 percent protein ration (Brinegar et al. 1949, 1950) 0.055 percent L-lysine is required for each 1 percent protein in the ration.

4/Based on 0.6 percent DL-methionine required in a 21.0 percent protein ration (Shelton et al. 1951) 0.0286 percent DL-methionine is required for each 1 percent protein in the ration.

5/Based on 0.2 percent DL-tryptophan required in a 24.5 percent protein ration (Shelton et al. 1951) 0.008 percent DL-tryptophan is required for each 1 percent protein in the ration.

percent L-lysine with this diet, which might indicate that the aureomycin in the ration was exerting an amino acid-sparing effect. During this period the antibiotic appeared to markedly stimulate the appetite of the animals receiving the 8 percent protein ration, resulting in greater daily feed consumption and consequently, a greater total protein intake.

The calculated and analyzed methionine contents of the rations were practically identical. As the proportion of corn in the diet increased, the methionine deficiency decreased, as would be expected since the limiting amino acid in soybean oil meal is methionine, and the 8.34 percent protein corn ration would appear to satisfy the calculated quantitative requirement for this amino acid, especially if allowance is made for the assumed cystine content of the ration.

Similarly it would appear from the calculations that tryptophan was not the primary limiting amino acid.

As presented graphically in Figure 5, lysine would appear to be the primary limiting amino acid on the lower protein levels.

To determine whether lysine supplementation would improve low-protein corn-soybean oil meal rations, it seemed advisable to use individual pig feeding. Group feeding was not believed an economically feasible approach to this problem and smaller differences could be measured with fewer animals when they were individually fed. Facilities available for individual feeding included 24 wire-bottom crates in each of two buildings in which heat was thermostatically controlled. In Building E the crates were of wood construction, 18 inches wide by 40 inches long, and had wire

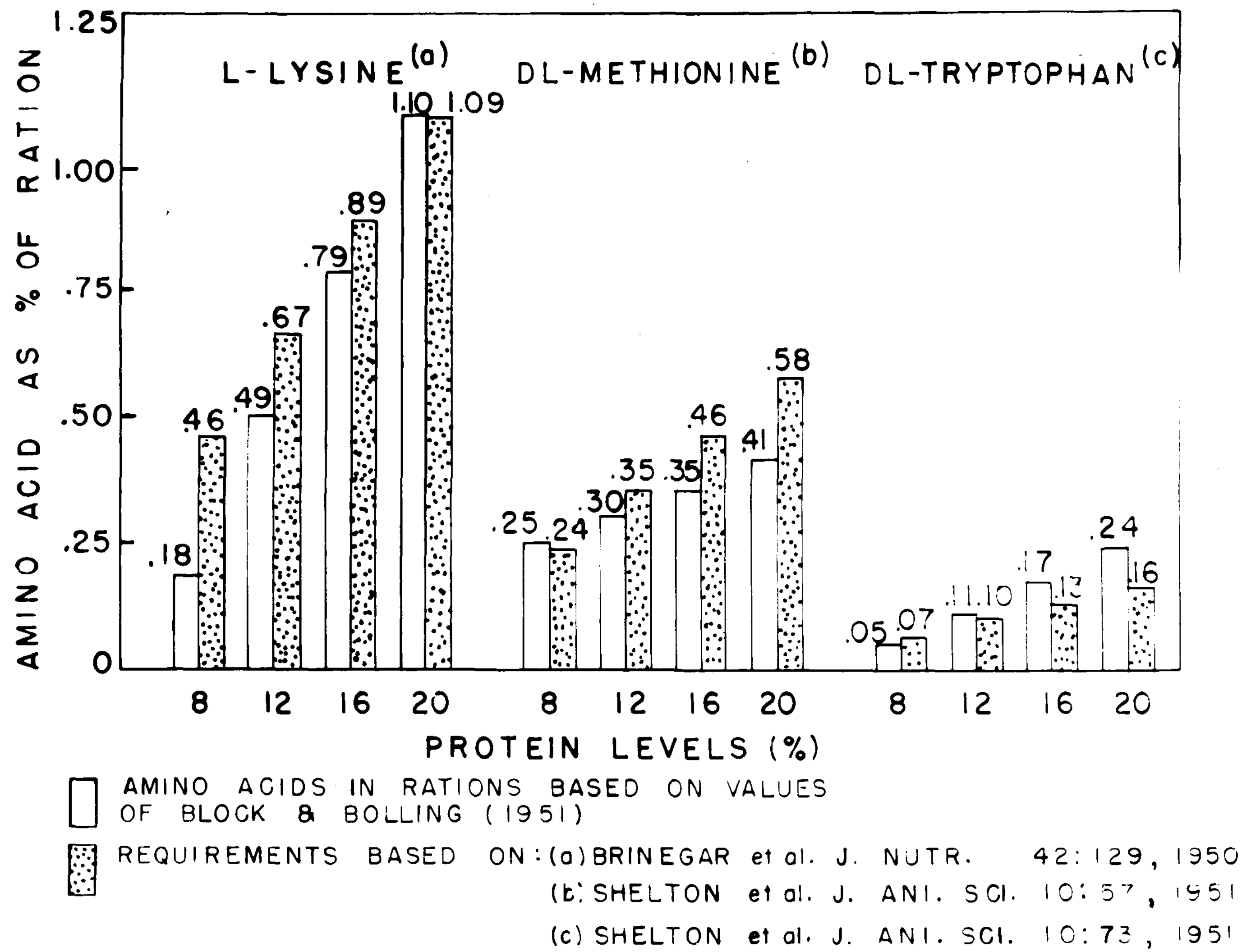


Fig. 5 Limiting amino acids in corn-soybean oil meal rations.

floors, with individual self-feeders and watering pans. The crates in Building F were all metal, with automatic waterers and feeders on each crate.

The design of these crates was such that individual collection trays could be placed under the pigs, permitting collection of fecal and urine excretions.

Experiment 544

Plan. The purpose of this experiment was to determine whether lysine supplementation to 10 and 12 percent protein-level corn-soybean oil meal rations affects rate of gain, feed efficiency and palatability.

Forty-eight Duroc pigs were allotted at random from outcome groups of eight pigs each. Each outcome group was as uniform as possible with regard to previous treatment, litter, condition, weight and sex. The dams of these pigs had received a good ration including animal protein, B-vitamins, minerals including trace minerals, and an aureomycin-B_{12} supplement (Aurofac).

All the pigs were wormed with NaFl and sprayed with benzene hexachloride prior to starting the experiment. Average initial weight was approximately 34 pounds and average age at time of allotment was 56 days. The pigs were allotted randomly to individual wire-bottom feeding crates, in which feed and water were available at all times. The feeding crates were washed down twice daily to reduce self-contamination through coprophagy.

The basal 12 percent protein ration and chemical analysis are shown in Table 15. The vitamin additions were made in amounts believed to be sufficient to prevent any one of them being a limiting factor of the ration.

Table 16 presents the percent of lysine in the respective treatments. Additions of 0, .02, 04, and .09 percent L-lysine were made to the 10 percent protein ration, and 0, .008, .015, and .03 percent to the 12 percent protein ration. The percentages were determined by 0, $\frac{1}{4}$, $\frac{1}{2}$, and the full difference between the microbiologically-assayed content of the amino acid in the ration and the theoretical quantity of lysine required by the growing-fattening pig on the respective protein levels. The 10 percent basal ration by microbiological assay contained .46 percent L-lysine and this ration theoretically should have contained .55 percent L-lysine to meet the requirement. Similarly, .63 percent of the 12 percent basal ration was L-lysine when theoretically it should have contained .66 percent.

Results and discussion. Table 17 gives a summary of the averages for daily gain, daily feed, and feed per 100 pounds of gain. The only significant difference was between the two protein levels fed, thus demonstrating that even with the amino acid supplementation, 10 percent protein was inadequate for optimum growth. Average daily gain for all pigs on the lower protein level was 0.92 pounds, while on the higher protein level it was 1.02 pounds. Pounds of feed required per 100 pounds of gain were 346 and 312 for the 12 and 10 percent protein levels, respectively.

Table 15. Composition of the basal ration.

	%
Ground yellow corn	89.0
Solvent soybean oil meal (blended)	5.0
Vitamin Premix No. 14[a]	2.0
Special steamed bonemeal	3.0
Calcium carbonate	.4
Iodized salt	.5
Trace mineral mixture[b]	.1
<u>Calculated analysis</u>	
Protein	9.963
Fat	3.42
Fiber	2.20
Calcium	1.095
Phosphorus	.669
Vit. A, I.U. per lb.	2180.0
Vit. D_2, U.S.P. units per lb.	400.0
Riboflavin, mg. per lb.	1.50
Niacin, mg. per lb.	18.50
Pantothenic acid, mg. per lb.	6.00
Choline, mg. per lb.	369

[a]Vitamin Premix No. 14 supplied the following amounts of vitamins per pound of ration:

Alpha-tocopherol acetate	1.5	mg.	Pyracin	1.0	mg.
Ascorbic acid	25.0	"	Pyridoxine	1.0	"
Biotin	0.2	"	Riboflavin	1.5	"
Calcium pantothenate	6.0	"	Thiamin	1.0	"
Choline chloride	450.0	"	Vitamin K	1.0	"
Folic acid	0.5	"	Vitamin A	2000.0	I.U.
Inositol	200.0	"	Vitamin D_2	400.0	U.S.P.
Niacin	20.0	"	Vitamin B_{12}	10.0	mcg.
Para-amino-benzoic acid	0.5	"			

[b]Contributed the following ppm to the ration: Fe-70, Co-1.6, Cu-4.8, Mn-59, Zn-4.4, and K-76.

Table 15 (Continued)

	Chemical analysis (percent)		
Lot(s)	Protein	Calcium	Phosphorus
1 + 9	10.08	1.09	0.72
2 + 10	10.63	1.06	0.68
3 + 11	10.24	1.10	0.68
4 + 12	10.69	1.20	0.70
5 + 13	12.13	1.06	0.66
6 + 14	12.70	1.20	0.74
7 + 15	13.02	1.23	0.73
8 + 16	13.28	1.29	0.75

	Microbiological assay of lysine (percent)	
Lot	Calculated	Found
1	0.46	0.49
2	0.48	0.50
3	0.50	0.55
4	0.55	0.61
5	0.63	0.72
6	0.638	0.77
7	0.645	0.77
8	0.66	0.82

Table 16. Protein and lysine values (percent).

Protein	L-lysine added	L-lysine content of ration
10	0.00	.46
	0.02	.48
	0.04	.50
	0.09	.55
12	0.00	.63
	0.008	.638
	0.015	.645
	0.03	.66

Table 17. Effect of lysine supplementation to different levels of protein.

L-lysine additions	10% protein Lysine (%)	10% protein Average	12% protein Lysine (%)	12% protein Average
		Daily gain		
0	0.46	0.92	0.630	1.04
0.25	0.48	0.92	0.638	0.97
0.50	0.50	0.96	0.645	0.96
1.00	0.55	0.87	0.660	1.10
Average		0.92		1.02
		Feed per 100 pound gain (pounds)		
0	0.46	350	0.630	313
0.25	0.48	341	0.638	315
0.50	0.50	342	0.645	318
1.00	0.55	351	0.660	302
Average		346		312
		Daily feed (pounds)		
0	0.46	3.22	0.630	3.26
0.25	0.48	3.14	0.638	3.06
0.50	0.50	3.28	0.645	3.05
1.00	0.55	3.05	0.660	3.32
Average		3.17		3.17

Average daily feed consumption was the same on the two protein level rations fed. That the .09 percent L-lysine equivalent disturbed palatability is evidenced by the lower average daily feed intake for those pigs receiving this ration.

Supplementation of the 10 percent protein ration with .02 percent and .04 percent L-lysine equivalent appeared to increase feed efficiency above that obtained on the basal ration. This difference, however, was not significant.

The 12 percent protein level ration containing the full addition of lysine produced the most rapid daily gain. Average daily feed consumption was highest on this ration, and these pigs required 18 pounds less feed per 100 pounds of gain than those animals on the 12 percent protein basal ration.

Data from the results of the first four replicates, which were started on trial January 22, 1952, strongly indicated an increasing response with higher supplementation of lysine to the 12 percent protein level. However, this trend was completely masked by the performance of the fifth and sixth replications, which were started February 28, 1952, five weeks later than the first four replicates. Different sources of corn were used; that used for the first replicates analyzed 7.44 percent protein and.26 percent L-lysine, while that for the last two replicates on the 12 percent protein level rations analyzed 7.14 percent protein and .31 percent L-lysine. The same source of soybean oil meal was used in all rations fed, this meal containing 44.3 percent protein and 3.3 percent L-lysine. Appropriate adjustments were made in the corn-soybean oil meal proportions and amino acid additions so that the L-lysine values on comparable rations were the same.

Microbiological assay of the rations fed to the last two replicates produced the data shown in Table 18. These data show that the basal 12 percent protein ration received by the last two replicates analyzed .72 percent L-lysine which was higher than the fully supplemented ration for the first four replicates. The 10 percent protein level rations do not show this apparent discrepancy. The reasons for the high lysine values on the 12 percent protein level are not known. Errors in ingredient analysis, in the mixing procedure, or in analysis of the final mixed rations may have contributed to the high values.

These analyses do, in part at least, explain the apparent ineffectiveness of added lysine for the fifth and sixth replicates. Upon the basis of a theoretical requirement of .66 percent L-lysine, the basal 12 percent protein level ration containing .72 percent L-lysine was more than adequate in that nutrient. Thus, higher levels of the amino acid would be of no apparent use to the animal, and the higher levels may have actually disturbed daily feed consumption. The average daily gains for the first four replicates and the last two replicates on the 12 percent protein rations were as follows: .97, 1.18; .93, 1.07; .94, 1.00; and 1.12, 1.05 pounds, respectively. Daily feed intakes were 3.23, 3.30; 3.15, 2.87; 3.14, 2.89; and 3.54, 2.88 pounds, respectively.

The apparent increase in feed efficiency with addition of .03 percent L-lysine to the 12 percent protein ration is supported by a report of Whitehair and Hillier (108) who stated that the addition of 0.2

Table 18. Ration analysis (percent).

Lot No.	Protein	Calcium	Phosphorus	Lysine Found	Lysine Calculated
1	10.08	1.09	0.72	0.49	(.46)
2	10.63	1.06	0.68	0.50	
3	10.24	1.10	0.68	0.55	
4	10.69	1.20	0.70	0.61	(.55)
5	12.13	1.06	0.66	0.72	(.63)
6	12.70	1.20	0.74	0.77	
7	13.02	1.23	0.73	0.77	
8	13.28	1.29	0.75	0.82	(.66)

percent lysine to an all-plant ration of 14 percent protein had little effect on gain, but improved feed efficiency about four percent. Whitehair and MacVicar (109) showed that during a 28-day feeding trial pigs of approximately 31 pounds initial weight gained more rapidly when lysine was added to an all-plant ration than when either methionine or a combination of amino acids were added.

Since the synthetic source of lysine was a DL-lysine hydrochloride, 40 percent L-lysine, for each gram of L-lysine supplementation it was necessary to add 2.50 grams of the DL-lysine mixture. Thus, the quantity of the D-lysine may have been largely responsible for the apparent palatability disturbance on the lower protein level rations. However, the addition of .03 percent L-lysine equivalent to the 12 percent protein ration did not noticeably affect the rate of consumption.

<u>Summary</u>. Supplementation of a 10 percent protein level corn-soybean oil meal ration with graded levels of the amino acid lysine did not improve the nutritive quality of the ration under the conditions of this experiment.

A corn-soybean oil meal ration containing 12 percent protein gave very satisfactory growth rate in pigs from weaning to 75 pounds live weight. The addition of .03 percent L-lysine equivalent increased rate of gain and feed efficiency.

<u>Experiment 553</u>

<u>Plan</u>. The purpose of this experiment was to further study the effect of lysine supplementation to low-protein corn-soybean oil meal

ration, and, in addition, it was desired to study the effect of the antibiotic aureomycin alone and in combination with lysine.

The rations used, shown in Table 19, were essentially the same as those previously mentioned. In this experiment, however, one source of corn supplied the quantity required for the entire feeding period. This corn analyzed 8.4 percent protein and .31 percent lysine and the soybean oil meal contained 44.1 percent protein and 3.3 percent lysine. Consequently, less of the oil meal was needed to obtain the desired protein levels and more synthetic lysine had to be added to the respective treatments than was the case in the previous experiment. The levels of protein fed and the percent of L-lysine equivalent added is shown in Table 20.

Using a 4 x 4 Balanced Lattice experimental design, 80 Duroc pigs were assigned to individual wire-bottom crates. Insofar as was possible four littermate pigs were randomly allotted within blocks. The average initial weight of the pigs was 25.3 pounds at an average initial age of 56 days. Growth and feed data were recorded each week and individual records were terminated when the pig reached 75 pounds live weight.

Immediately following termination of these records, nitrogen balance studies were made on each pig, using the same crates in which the pigs had been confined throughout the feeding period. Using red iron oxide as a marker, a 72-hour collection was taken with the pig still feeding <u>ad libitum</u>. After the second marker appeared in the fecal material, the animal was placed on a limited feed intake of 1.5 pounds twice daily. The selection of this quantity of feed was based on

Table 19. Composition of 12 percent protein ration.

	%
Ground yellow corn	85.5
Solvent soybean oil meal (blended)	8.5
Vitamin Premix No. 14[a]	2.0
Special steamed bonemeal	3.0
Calcium carbonate	0.4
Iodized salt	0.5
Trace minerals[b]	0.1
Calculated analysis	
Protein	12.052
Fat	3.301
Fiber	2.340
Calcium	1.088
Phosphorus	.641
Vit. A, I.U. per lb.	2255.0
Vit. D_2, U.S.P. units per lb.	400.0
Riboflavin, mg. per lb.	1.5
Niacin, mg. per lb.	18.74
Pantothenic acid, mg. per lb.	6.53
Choline, mg. per lb.	408

[a]Vitamin Premix No. 14 supplied the following amounts of vitamins per pound of ration:

Alpha-tocopherol acetate	1.5	mg.	Pyracin	1.0	mg.
Ascorbic acid	25.0	"	Pyridoxine	1.0	"
Biotin	0.2	"	Riboflavin	1.5	"
Calcium pantothenate	6.0	"	Thiamin	1.0	"
Choline chloride	450.0	"	Vitamin K	1.0	"
Folic acid	0.5	"	Vitamin A	2000.0	I.U.
Inositol	200.0	"	Vitamin D_2	400.0	U.S.P.
Niacin	20.0	"	Vitamin B_{12}	10.0	mcg.
Para-amino-benzoic acid	0.5	"			

[b]Contributed the following ppm to the ration: Fe-70, Co-1.6, Cu-4.8, Mn-59, Zn-4.4, and K-76.

Table 19 (Continued)

	Analyses of rations (percent)			
Calculated	Found*			
Lysine	Protein		Lysine	
	-Aureomycin	+Aureomycin	-Aureomycin	+Aureomycin
0.447	9.82	9.73	0.43	0.39
	10.88	10.66	0.47	0.40
	11.23	10.96	0.40	0.40
0.467	9.98	10.21	0.46	0.42
	10.35	11.09	0.39	0.40
	10.72	10.45	0.39	0.41
0.495	10.14	10.46	0.50	0.45
	10.90	10.86	0.44	0.45
	10.77	10.61	0.54	0.45
0.560	9.83	10.46	0.53	0.48
	10.85	10.85	0.46	0.40
	10.30	10.56	0.55	0.47
0.620	12.76	12.58	0.62	0.47
	13.01	12.39	0.47	0.49
	12.34	12.54	0.53	0.53
0.637	11.70	12.47	0.62	0.62
	12.13	12.86	0.50	0.55
	13.11	13.11	0.59	0.59
0.654	12.47	12.54	0.59	0.79
	12.31	12.60	0.57	0.56
	13.29	13.20	0.58	0.58
0.680	12.62	12.50	0.59	0.81
	13.31	13.10	0.57	0.60
	13.16	13.06	0.64	0.64

*These represent analysis of three different mixes.

Table 19 (Continued)

	Chemical Analysis			
Calculated			Found*	
Lysine	Calcium	Phosphorus	Calcium	Phosphorus
0.62	1.08	0.62	1.03	0.60
			1.05	0.64
			1.14	0.60
			1.02	0.61
0.637	1.09	0.64	1.05	0.68
			1.08	0.65
			0.93	0.62
			1.09	0.68
0.65	1.07	0.62	1.03	0.64
			1.09	0.69
			1.14	0.66
			1.03	0.60
0.680	1.09	0.64	0.98	0.62
			1.15	0.64
			1.06	0.62
			1.09	0.64

*Each figure represents an average of the analysis of three different mixes.

Table 20. Lysine addition to 10 and 12 percent protein rations.

Protein	L-lysine added	L-lysine in ration
10	0.000	0.447
	0.027	0.467
	0.055	0.495
	0.110	0.560
12	0.000	0.620
	0.017	0.637
	0.034	0.654
	0.069	0.680

average rates of consumption during the experiment. This quantity would not be in excess for those individual pigs which had consumed the least feed during ad libitum feeding, yet it would be sufficient to permit an appreciable rate of growth. After four days for adjustment to the new regime, a second 72-hour collection was made with the animals on this limited feed intake.

The feces from each pig were collected twice daily and placed in a glass jar which was stored in a refrigerator. Enough acidified distilled water was added to provide a semi-liquid consistency, with 20 cubic centimeters of toluene forming a seal over the surface of the mixture. The resulting fecal solution had a pH range of 4 to 5.

Aliquots of two cubic centimeters per 100 cubic centimeters of urine collected were placed in test tubes containing two cubic centimeters of toluene, and were stored in the refrigerator.

At the end of the collection period, the total fecal collection for each pig was thoroughly mixed and a 300-gram representative sample was taken for chemical analysis. At the same time a 10 cubic centimeter aliquot of the composite urine sample was taken for analysis.

Total nitrogen contents of the rations, feces, and urine were determined by the Kjeldahl method.

Biological values were measured by calculation since the time available, the number of pigs used, and the labor involved prohibited actual measure of metabolic fecal and endogenous nitrogen from the individual pigs. Other workers have shown a high correlation between measured and calculated values. Further, the pigs were all of approximately 75 pounds live weight when the collections were made, thus minimizing possible variations of endogenous nitrogen values due to size of the animal, assuming that this excretion is a function of the body's functional tissue constituents (94, 71, 12).

The metabolic fecal nitrogen was computed on the basis of 1.8 grams of nitrogen of body origin excreted for each one thousand grams of dry matter consumed (9). Endogenous nitrogen was determined by the formula: $N_{(\text{milligrams})} = 146\ W_{(\text{kilograms})}^{0.72}$, where N stands for nitrogen and W for body weight. The biological values were then calculated using the formula of Mitchell (70) and Mitchell et al. (74), which was believed most applicable to the problem. These values represent the percent of the nitrogen absorbed that was actually retained.

Results and discussion. Table 21 presents the summary of the averages of daily gains, daily feed, and feed required per 100 pounds of gain on the different treatments. The average daily gains obtained with the pigs receiving the 12 percent protein rations were significantly greater than the average daily gains of all the pigs receiving 10 percent protein.

No differences were obtained with supplementation of lysine and/or aureomycin to the 10 percent protein level ration. With the 12 percent protein rations, however, the average daily gains of all animals showed a significant increase with lysine supplementation. In the absence of

Table 21. Effect of lysine and antibiotic (aureomycin) supplementation on low protein level rations for growing-fattening swine.[1]

Lysine[2] additions	10% Protein				12% Protein			
	Lysine (%)	No aureo.	10 mg. aureo./lb.	Average	Lysine (%)	No aureo.	10 mg. aureo./lb.	Average
				Average daily gains (pounds)				
0	0.447	0.93	0.83	0.88	0.611	1.06	0.99	1.02
0.25	0.474	0.77	0.81	0.79	0.628	1.13	1.12	1.12
0.50	0.502	0.77	0.82	0.80	0.645	1.15	1.07	1.11
1.00	0.557	0.76	0.88	0.82	0.680	1.18	1.18	1.18
Average		0.81	0.84	0.82		1.13	1.09	1.11
				Feed per 100 pound gain (pounds)				
0	0.447	325	336	330	0.611	274	280	277
0.25	0.474	344	350	347	0.628	270	268	269
0.50	0.502	326	326	326	0.645	262	276	269
1.00	0.557	360	313	337	0.680	257	252	254
Average		339	331	335		266	269	267
				Average daily feed (pounds)				
0	0.447	3.02	2.77	2.89	0.611	2.90	2.76	2.83
0.25	0.474	2.66	2.81	2.73	0.628	3.04	2.98	3.01
0.50	0.502	2.51	2.64	2.58	0.645	3.01	2.91	2.96
1.00	0.557	2.72	2.70	2.71	0.680	3.03	2.97	3.00
Average		2.72	2.73	2.73		2.99	2.91	2.95

[1] Five pigs per treatment individually fed (total 80). Average initial weight 25.3 pounds. Average final weight 75 pounds.

[2] Proportion of difference between percent lysine in ration and that required.

the antibiotic, the trend in growth rate followed the lysine content of the ration. With aureomycin added, this trend, though less consistent, also existed.

Feed consumed per pig per day was extremely variable when the 10 percent protein rations were fed without the aureomycin. It was evident that in general the palatability of the lower protein ration was less desirable than that of the higher protein level and in certain cases this unpalatability appeared to be accentuated with increasing quantity of the synthetic lysine.

Including the antibiotic in the rations apparently reduced this variability. It is possible that in the presence of the aureomycin the feed was more palatable.

Considering all the animals, those on the 12 percent protein level rations consumed .22 pound more feed per day than did those on the lower protein level ration, this difference being significant.

With the higher protein level rations the average daily feed consumption increased significantly with increased lysine level.

The feed efficiency reflected the average daily gains. The feed data show a great variability when considering the 10 percent protein rations. The data recorded do not represent the exact feed requirements since they were confounded with uncontrollable feed wastage. Therefore, the feed efficiency discussion will be confined to the higher protein level rations, since the data from those diets were an accurate measurement of the proceedings.

The animals receiving the 12 percent protein ration required significantly less feed per unit of gain than did those animals on the 10 percent protein rations. When considering only the pigs on the former rations, in the absence of the antibiotic there was a consistent decrease in feed required per 100 pounds of gain with each increment of lysine. This trend was also indicated by the data from those animals which had received aureomycin in the rations. All the pigs receiving the 12 percent protein ration plus 0.069 percent L-lysine required only 254 pounds of feed for each 100 pounds of body weight gain, as compared to 277 pounds for the 12 percent protein ration with no lysine added.

Contrary to our group feeding experiments, these individually fed pigs did not respond to the use of aureomycin in the rations. Whereas previously the antibiotic had stimulated growth rate, feed consumption, and increased feed efficiency, there were no differences in this experiment. This may suggest that confinement to the wire-bottomed cages and limited coprophagy reduced the disease contamination to the point where the antibiotic was ineffectual as a growth stimulant (25).

A total of six pigs receiving the 10 percent protein rations were removed from the experiment because of very slow growth, but this lack of growth was apparently independent of the lysine level fed.

Table 22 shows the resulting biological values. Calculations were made without considering the metabolic fecal nitrogen and the endogenous nitrogen. Then calculations were made taking both nitrogen fractions into consideration. As would be expected the latter values were higher

Table 22. Biological values.

Lysine %	Before adjustment for MFN and endogenous nitrogen[1]		After adjustment for MFN and endogenous nitrogen[2]	
	-Aureomycin	+Aureomycin	-Aureomycin	+Aureomycin
	Ad libitum feeding			
0.611	60.35	59.07	65.89	64.89
0.628	60.36	56.15	64.97	61.56
0.645	62.58	67.40	67.78	73.03
0.680	65.22	59.76	70.14	65.42
Average	62.13	60.59	67.19	66.22
	Limited feed intake			
0.611	54.33	60.01	60.57	66.36
0.628	52.50	55.33	60.09	61.94
0.645	56.18	56.94	62.86	63.62
0.680	58.27	58.21	64.72	64.37
Average	55.32	57.62	62.06	64.07
Total average	58.72	59.11	64.63	65.15

1/ $$\text{B.V.} = \frac{\text{N consumed} - (\text{N in feces} + \text{N in urine})}{\text{N consumed} - \text{N in feces}} \times 100$$

2/ $$\text{B.V.} = \frac{\text{N consumed} - \big((\text{N in feces} - \text{MFN}) + (\text{N in urine} - \text{EN})\big)}{\text{N consumed} - (\text{N in feces} - \text{MFN})} \times 100$$

MFN = Metabolic Fecal Nitrogen
EN = Endogenous Nitrogen

because of not penalizing the dietary nitrogen with the nitrogen of body origin. The percentages shown are for the 12 percent rations only. Values realized from the animals receiving 10 percent protein were extremely variable and could not be considered valid measurements. These erratic results were due to the apparent unpalatable nature of the ration, with the resulting unavoidable wastage of feed and contamination of the collections.

Statistical analysis of the data showed that the only significant difference among the lysine levels was the cubic component. This demonstration that the values for the lysine levels varied in this manner does not lend itself to immediate biological interpretations. As shown graphically in Figure 6, the .017 percent L-lysine equivalent addition to the ration appeared to be deleterious to nitrogen utilization, whereas the higher levels appeared to be beneficial. It would seem rather unlikely that the explanation lies with palatability, or imbalance of amino acids.

Considering the differences in values on the two types of feeding, ad libitum and limited, the collections made during the former method yielded values that were significantly higher than those made during the latter method. This, too, is contrary to that which would be expected, based upon the statements that the degree of utilization of nitrogen will decrease with increased intake (73).

In the absence of the antibiotic on the limited feed intake, there was a definite, though not statistically significant, trend toward

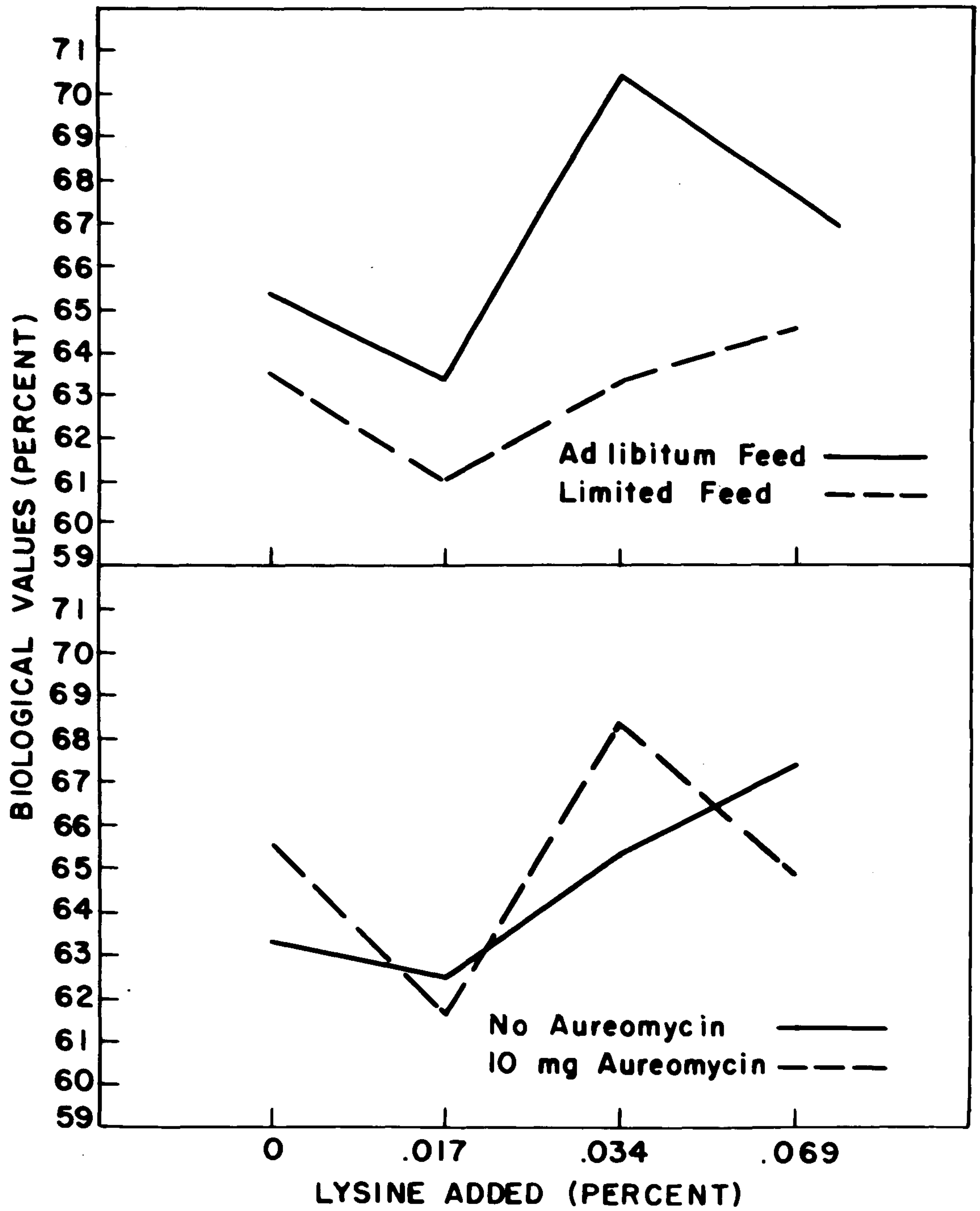


Fig. 6 Average biological values from pigs receiving 12 percent protein.

higher biological value with increasing lysine content of the ration. This is as one would expect if lysine were the primary limiting amino acid in the basal ration, and this trend is similar to the one on average daily gains in the absence of the antibiotic. With *ad libitum* feeding of non-antibiotic rations during the collection period, the biological values also reflected the average daily gains obtained on the respective treatments, but the trend is not as definite as from fixed feedings.

With aureomycin in the rations the biological values varied considerably. On a fixed intake of feed, the basal ration had a biological value of 66.36 percent. With *ad libitum* feeding the ration having .034 percent L-lysine added gave the highest value of all, 73 percent.

The antibiotic added at the rate of 10 milligrams per pound of ration did not significantly affect the utilization of nitrogen. This finding is similar to that of Brown (21) who reported that nitrogen-balance was not influenced by aureomycin when the paired-feeding technique was used.

When comparing the biological values and average daily gains, it should be remembered that the gains represent an average daily increase in weight over the entire period up to 75 pounds in weight. Thus, the figures representing gains do not indicate at what rate growth, as measured by increase in body weight, was occurring during the period in which the fecal and urine collections were made, nor do the biological values at this given weight indicate what variation may have existed during the feeding trial.

Had facilities and time not been limited, a longer collection period might have proved advantageous and a record of increase in body weight during this same period would have permitted a study of the correlation between the biological values and the tissue deposition.

Although the variations in biological values did not prove to be statistically significant, it is suggested by the author that there could very well be real differences existing in the biological value of the rations concerned. To show these differences, however, would require metabolism cages designed specifically for this type of study so that all possible prevention could be exercised against loss and/or contamination of the excretory products. Only with such equipment and refined technique can one adequately measure and detect the small, but real, differences which might exist.

Table 23 shows the apparent and true digestibility coefficients for the 12 percent protein rations. The digestibility did not appear to be affected by the different treatments.

Summary. Eighty Duroc pigs, confined to individual wire-bottom cages were fed corn-soybean oil meal rations, fortified with vitamins and minerals including trace minerals. Ten and 12 percent levels of protein were fed with 0, .027, .055 and .11 percent and 0, .017, .034, and .069 percent L-lysine additions, respectively. Half of the pigs on each treatment received 10 milligrams of aureomycin per pound of feed.

Table 23. Apparent digestibility coefficient.[1/]

Lysine	Ad libitum -Aureomycin	Ad libitum +Aureomycin 10 mg.	Fixed feed intake -Aureomycin	Fixed feed intake +Aureomycin 10 mg.
0.611	81.28	83.43	82.15	84.59
0.628	85.47	86.30	82.51	85.46
0.645	86.08	84.03	84.87	83.94
0.680	84.37	85.64	82.67	86.60
Average	84.30	84.85	83.05	85.15
Average *ad libitum*	84.57		Average fixed	84.10
		True digestibility coefficients[2/]		
0.611	86.98	91.51	90.53	93.62
0.628	93.71	95.18	91.59	94.22
0.645	94.70	92.04	93.67	92.78
0.680	91.56	93.63	91.27	95.24
Average	91.74	93.09	91.76	93.96
Average *ad libitum*	92.41		Average fixed	92.86

1/ $ADC = \frac{\text{N consumed} - \text{N in feces}}{\text{N consumed}} \times 100$

2/ $TDC = \frac{\text{N consumed} - (\text{N in feces} - \text{MFN})}{\text{N consumed}} \times 100$

The 10 percent protein rations were quantitatively and qualitatively inadequate for growth of the weanling pig from 25 to 75 pounds live weight.

Average daily gains and average daily feed increased significantly with addition of lysine to the 12 percent protein level ration. Feed efficiency was increased, though not significantly, indicating that lysine was the primary limiting amino acid.

Biological values were calculated from determined nitrogen-balances, with no significant differences among the different lysine levels in the 12 percent protein ration. Collections made during _ad libitum_ feeding resulted in significantly higher biological values than those obtained during limited intake.

There was no apparent stimulation in growth or feed efficiency by the feeding of the antibiotic.

GENERAL DISCUSSION

Recognizing the predominance of corn and soybean oil meal as ingredients in swine rations, these studies were conducted to determine the optimum protein levels for growing-fattening swine. Since the study of protein can not be divorced from the study of amino acids, the second phase of these studies was directed toward an increase in the quality of the all-plant protein mixture with additions of comparatively minute quantities of an amino acid. That the actual requirement for protein may be affected by the presence of an antibiotic(s) was also considered.

The highly efficient utilization by swine in drylot of an all-plant ration is realized to its greatest extent when supplementation of the ration is made with those known vitamins and minerals which are not sufficiently concentrated in the natural ingredients to meet the pig's needs. In effect, the search for those right proportions of all of the nutrients required to comprise a perfectly balanced ration has resulted in formulations of rations which produce increasingly greater gains and feed efficiency.

That this balanced ration concept is nutritionally justifiable has again been shown by the experiments herein reported.

In Experiment 506 the feeding of corn-soybean oil meal rations fortified with vitamins and minerals to 128 pigs from weaning to market weight demonstrated that protein levels for optimum growth are lower than those previously recommended. It was further shown that with the antibiotic aureomycin included in the rations at a level of 10 milligrams per pound of ration, growth response was obtained which was equal to that realized from non-aureomycin rations containing two or more additional percentage units of protein.

That the equal and better responses on less protein were attributable to a better balance of nutrients was further verified in Experiment 527. Corn alone, with a protein content of approximately 8 percent, supplemented with vitamins and minerals was completely inadequate for satisfactory growth in weanling crossbred pigs. These pigs averaged 37 pounds and after a period of eight weeks had gained only an average of 0.32 pound per day. The addition of sufficient soybean oil meal to raise the protein content of the ration to 12 percent resulted in a ration which produced 0.84 pound greater daily gain and required 318 pounds less feed for each 100 pounds of gain. The addition of vitamin B_{12} and the antibiotic aureomycin to the latter ration further improved growth response and feed efficiency.

The corn diet appeared to be unpalatable and thus a reduced feed intake accentuated the inadequacy of the ration. It is presumed that the marked difference in response to the 8 and 12 percent protein level rations was a result of the improved amino acid balance due to the supplemental effect of the proteins in the corn and soybean oil meal.

The feeding of the same protein level throughout the period from weaning to market weight in Experiment 536 supported the results of the first two feeding trials. In the absence of an antibiotic(s) 10 percent protein level corn-soybean oil meal rations were inadequate for optimum growth response. In this trial neither of the antibiotics used, aureomycin or terramycin, appeared to alleviate the nutritive inadequacy of this low protein level.

Including an antibiotic, aureomycin or terramycin, in the ration resulted in comparable daily gains on 2 to 4 percent lower protein levels. Pigs receiving 14 percent protein level rations from weaning to 75 pounds live weight gained as rapidly or more rapidly than pigs receiving higher protein levels. The increased feed efficiency with the addition of an antibiotic(s) did not prove to be statistically significant under the conditions of these experiments.

Based upon the results of these studies, it is recommended that when feeding a corn-soybean oil meal ration fortified with vitamins (riboflavin, niacin, pantothenic acid, thiamin, folic acid, vitamin B_{12}) minerals including trace minerals, and aureomycin, to pigs in drylot, levels of 14, 12, and 10 percent protein be fed for the weight periods of weaning to 75, 75 to 150, and 150 to 200 pounds. In the absence of the antibiotic, protein levels should be increased two percentage units for each of the respective periods. If it is desirous to feed one protein level from weaning to market weight it is suggested that 14 percent be fed. A lower level may result in an undesired increase in carcass fat. Slight variations from this level could be used if the relative costs of soybean oil meal and corn made it economically advisable.

That the above recommendations may not meet the protein needs of the pig under certain circumstances is recognized. These values assume that the corn and soybean oil meal used are of average nutritive quality, especially with regard to amino acids. It is conceivable that a very low or very high protein corn would appreciably alter the proportions of the two ingredients and thus increase or decrease the quality of the protein mixture sufficiently to change the quantitative protein requirement 2 or 3 percent.

Percentage value recommendations just mentioned take into account also the influence of ration fed upon the carcass being produced. When fed continuously, protein levels below 14 percent produced carcasses that contained a greater proportion of fat than did carcasses from those animals which received higher protein levels.

Antibiotic(s) inclusion in rations does not adversely affect the quality of the carcass of a hog slaughtered at approximately 200 pounds live weight. That antibiotic feeding may even enhance the desposition of lean tissue on medium and low level protein rations has been noted (112). However, an apparent increase in fat content when the antibiotic-B_{12} feeding supplement was fed was suggested when percent of the lean cuts was measured (82).

In these studies the use of specific gravity and percent lean cuts measurements were much more indicative of carcass composition than was any other measurement. Thickness of back-fat was not sufficiently sensitive to use as a criterion for measuring carcass fatness.

Selection of 10 and 12 percent protein levels for amino acid supplementation was based on the premise that a protein level below that producing optimum growth would give a greater response to the addition of the primary limiting amino acid. Further, this supplementation may improve the amino acid balance to a degree which would permit these protein levels to produce growth rates equivalent to those produced on the slightly higher levels. If the growth rate was not increased, there might be an improvement in feed utilization.

Experiment 544 indicated that supplementation of a corn-soybean oil meal ration with excess DL-lysine decreases palatability and thus indirectly suppresses growth. This was true on the 10 percent protein level ration when .09 percent L-lysine equivalent was added. The reluctance to consume this ration corroborates earlier observation of decrease in palatability with an added racemic mixture of lysine (49). It also supports the reported unavailability of the D form of lysine for growth (55,4).

It would not appear that depression in growth was entirely a function of amino acid imbalance since of the ten essential amino acids only lysine, methionine, and valine depressed growth when fed to excess to rats (87). Unsatisfactory response could not be attributed solely to insufficient protein _per se_ since pigs of similar weight have gained very satisfactorily on purified diets containing 11.3 percent protein equivalent, 3.9 percent of which was supplied as diammonium citrate (68).

The addition of .03 percent L-lysine equivalent to the 12 percent protein ration appeared to improve the amino acid balance of the ration as less feed was required per unit of gain from that ration than from the unsupplemented ration.

Experiment 553 demonstrated very clearly the inadequacy of the 10 percent protein level corn-soybean oil meal rations for weanling pigs. Erratic growth rates and inconsistent feed efficiency data preclude further evaluation of this ration.

With 12 percent protein in the ration, a significant increase in growth rate was obtained with increasing levels of lysine in the ration. Daily feed consumption was very similar on all rations, but the addition of .069 percent L-lysine equivalent gave an apparent 8 percent increase in feed efficiency. This is evident proof of lysine's being the primary limiting amino acid in the corn-soybean oil meal ration at the 12 percent protein level and supports the supposition that the amino acid requirement is in proportion to the protein in the diet.

Effectual response of lysine supplementation can be expected to vary with different proportions of corn to soybean oil meal in rations. The quantitative need for the supplemental amino acid is inversely related to the proportion of corn to soybean oil meal, which in turn will be dependent upon the protein content of the two ingredients. Corn containing 9 percent protein will represent a greater portion of the mixed ration than would corn containing 7.5 percent protein, assuming the protein content of the soybean oil meal to be constant. Consequently, assuming that variation in corn protein quantity does not appreciably affect its quality, more supplementary lysine would be required for the former than for the latter ration. The validity of these statements also rests upon an assumed consistent average nutrient composition of the ration ingredients, especially of the vitamins.

Calculated biological values from a nitrogen-balance determined on each pig did not give a clear cut picture of the effect of lysine supplementation upon the utilization of the protein consumed. With the 10 percent protein level rations the variation of the data was of a magnitude which did not permit logical biological interpretation. Considering all the measurements from those animals receiving 12 percent protein, there was an apparent but unexplainable decrease in percent nitrogen retained when .017 percent L-lysine equivalent was added to the ration. An apparent beneficial effect was obtained, however, when .034 or .069 percent L-lysine equivalent was added to the ration.

The apparent adverse effect of the addition of .017 percent L-lysine equivalent could conceivably represent a difference in rate of absorption from the intestinal tract. Absorption of the synthetic amino acid may have been more readily accomplished than that of the amino acids in the feed protein. Had the rate of absorption of the former been sufficiently more rapid than that of the latter, it is not completely illogical to assume that a goodly proportion may have been catabolized before the amino acids from the feed were sufficiently absorbed and available for protein synthesis in the body. If such were the sequence, a relatively higher exogenous nitrogen value would result, proportionately reducing the percent of nitrogen retained.

That the higher levels of supplementation may result in increased biological values suggests that the time required for absorption of the synthetic fraction would be in proportion to the amount consumed. Thus, a portion of the protein amino acids would be available for metabolism along with the latter portions of the synthetic lysine to permit simultaneous occurrence for protein synthesis in the body.

Feeding the animals ad libitum during the collection period resulted in significantly higher biological values than when feed intake was limited to 1.5 pounds twice daily. This does not support the accepted belief that efficiency of utilization of protein decreases with increasing dietary nitrogen intake. Presuming the amino acid requirements for maintaining the nitrogenous integrity of the tissues to be simpler than those for construction of new protein molecules, it would seem that the limited intake diet would be more efficiently utilized since the greater proportion of the nutritive value would be necessary for maintenance. The 3.0 pounds per day fixed intake was sufficient to permit a degree of growth, as was indicated by the positive nitrogen-balances obtained; however, the utilization of nitrogen appeared to be less than when a greater quantity of feed was consumed. It is possible that with the limited intake of feed, the nitrogen contributed by the synthetic lysine, especially that from the D isomer of the mixture, contributed to that portion which was metabolically unavailable, thus increasing the exogenous nitrogen.

Further, it may be suggested that the level of dietary nitrogen consumed during the *ad libitum* intake period was more nearly ideal for measuring the biological value of this protein in promoting growth, since a greater quantity of the nitrogen was retained (73).

Considering all biological values on the 12 percent protein ration, the trend toward higher values with increasing lysine content of the ration indicates a beneficial effect upon the quality of protein consumed. The inclusion of aureomycin in the rations did not appear to enhance protein utilization.

The apparent and calculated true digestibilities of the dietary nitrogen did not evidence any treatment effect.

SUMMARY

The experiments reported herein were conducted to determine the optimum levels of protein in corn-soybean oil meal rations for growing and fattening pigs and to study the effects of antibiotic and lysine supplementation on different protein levels.

In feeding pigs under drylot conditions, balanced rations permitted use of lower protein levels. It was shown that levels of 16, 13, and 10 percent protein for the periods of growth from weaning to 75, 75 to 150, and 150 to 200 pounds, respectively, produced growth rates equal to and greater than those obtained with either two or four added percentage units. With 10 milligrams of aureomycin added per pound of ration, the protein level series of 14, 11, and 8 percent produced growth rates equal to that obtained with 6 percent more protein. During the period of growth from 150 to 200 pounds, 8 percent protein (corn alone plus vitamins and minerals) supported an average daily gain of 1.54 pounds while the addition of 10 milligrams of aureomycin per pound of ration resulted in gains of 1.88 pounds per day.

For pigs from weaning to approximately 100 pounds live weight, corn alone supplemented with vitamins and minerals was inadequate. Addition of 10 micrograms of vitamin B_{12} and/or 10 milligrams of aureomycin did not consistently improve growth response. In the absence of the antibiotic, 16 percent protein level rations produced faster gains and were

more efficient than 12 or 20 percent protein level rations. With aureomycin in the rations a 16 percent protein was still superior and 12 percent protein level rations resulted in more rapid gains than did 20 percent protein level rations.

When pigs were fed the same protein levels from weaning to 200 pounds live weight 10 percent protein levels were inadequate for optimum growth whether fed with or without either aureomycin or terramycin at 5 milligrams per pound of ration. In the absence of an antibiotic 16 and 18 percent protein level rations produced the most rapid rate of gain. When 5 milligrams of either aureomycin or terramycin were included in the rations 14 percent protein resulted in the highest growth rate and feed efficiency.

As shown by carcass measurements, the proportion of fat to lean reflected the protein content of the rations fed. Using specific gravity values as a criterion, a significant increase in lean content of the carcass was obtained with increasing protein content (10 to 18 percent of the rations fed). Calculation of the percent lean cuts also showed an inverse relationship of fat content of the carcass to protein level in the ration fed.

With pigs fed in individual wire-bottom crates, lysine supplementation to 10 percent level corn-soybean oil meal rations did not stimulate growth or feed efficiency. In fact, the higher levels of lysine appeared to depress feed consumption and growth, although this effect was not significant.

Adding lysine to corn-soybean oil meal rations of 12 percent protein resulted in increased growth rate and feed efficiency. When .069 percent L-lysine equivalent was added to the ration in the second experiment, average daily gains were significantly increased. The amount of feed required for each 100 pounds of gain was 12 pounds less than when no synthetic lysine was added.

The inclusion of 10 milligrams of aureomycin per pound of ration appeared to reduce the variation in feed consumption of those pigs receiving the 10 percent protein level rations. Apparently, the antibiotic favorably affected palatability of the rations.

With the 12 percent protein rations the antibiotic had no measurable effect on growth response, feed consumption and feed efficiency.

Biological values, as calculated from nitrogen-balance data, on the 12 percent protein level rations tended to increase with increasing L-lysine supplementation. Although this trend was not significant it supported the growth response and feed efficiency data, thus indicating lysine to be the primary limiting amino acid in these corn-soybean oil meal rations.

CONCLUSIONS

Data from group-feeding trials involving a total of 352 pigs and from individual feeding trials involving 128 pigs, all of which were fed corn-soybean oil meal rations, provide bases for the following conclusions:

1. Previously recommended protein levels for growing-fattening swine were in excess of the pig's needs for optimum growth and feed efficiency when balanced corn-soybean oil meal rations were fed.
2. With nutritionally balanced rations, a level of 16 percent protein produced rapid and efficient gains for the weanling pig. For the weight periods from 75 to 150 pounds and 150 to 200 pounds, protein levels of 13 and 10 percent, respectively, were adequate under dry-lot conditions.
3. With either aureomycin or terramycin, at the rate of 5 milligrams per pound of total ration, satisfactory growth rate and feed efficiency resulted when 14, 12, and 10 percent protein levels were fed during the previously stated weight periods.
4. When the same ration was fed from weaning to 200 pounds, a 16 percent protein level proved most satisfactory, while 14 percent protein was optimum if 5 milligrams of either aureomycin or terramycin was included per pound of ration.
5. Antibiotic feeding at practical levels did not adversely affect the quality of the carcass produced.

6. The use of antibiotics in these group-feeding studies were beneficial in the control of scouring in the animals receiving the higher protein levels.
7. The use of antibiotics did not consistently improve 8 and 10 percent protein level rations, which were definitely inadequate for optimum growth and feed efficiency.
8. Carcass quality, as related to proportions of fat and lean, was significantly affected by the level of protein in the rations fed. The amount of fat in the carcass was inversely related to protein level fed.
9. Back-fat measurements were not reliable in indicating fatness of carcass. Specific gravity values and percent of lean cuts more closely indicated the fat content of the carcass.
10. Ten percent corn-soybean oil meal rations were not nutritionally improved by the addition of synthetic DL-lysine.
11. Supplementation of 12 percent corn-soybean oil meal rations with sufficient DL-lysine to provide .069 percent L-lysine resulted in increased daily gain and feed efficiency.
12. Biological values as calculated from nitrogen-balances on those pigs receiving 12 percent protein were increased with lysine supplementation, indicating this amino acid to be the limiting one in the rations fed.

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APPENDIX

Table A (Continued)

	Average daily feed Protein levels (%)			
Initial to 75 lbs.	20	18	16	14
75 to 150 lbs.	17	15	13	11
150 to 200 lbs.	14	12	10	8
No Aureomycin				
Initial to 75				
Rep. 1	3.59	3.33	3.99	3.43
Rep. 2	3.28	3.30	3.07	3.02
75 to 150				
Rep. 1	6.23	6.58	6.29	6.28
Rep. 2	6.13	6.10	6.39	5.99
150 to 200				
Rep. 1	8.17	8.92	8.80	6.93
Rep. 2	8.10	7.63	8.50	7.33
10 mg. Aureomycin				
Initial to 75				
Rep. 1	3.11	3.24	3.51	3.11
Rep. 2	3.09	2.84	3.48	3.39
75 to 150				
Rep. 1	6.12	6.40	6.67	6.52
Rep. 2	6.88	6.25	6.39	6.79
150 to 200				
Rep. 1	8.15	8.46	8.02	8.46
Rep. 2	8.73	8.92	7.66	8.08

1/Eight pigs on each level of protein in each replicate.

2/The gain of one pig was estimated from 150 to 200 pound (Snedecor, 1946) as it did not respond normally.

3/The gain of one pig which died of a physiological disorder not attributable to nutrition was estimated.

Table B. Analyses of variance. Experiment 506.

Sources of variation	Degrees of Freedom	Daily Gain			Feed per 100 lbs. gain		
		to 75 lbs. Mean Square	75 to 150 lbs. Mean Square	150 to 200 lbs. Mean Square	to 75 lbs. Mean Square	75 to 150 lbs. Mean Square	150 to 200 lbs. Mean Square
Replications	1	0.0039	0.0060	0.0049	589	182	253
Aureomycin	1	0.0116	0.1463	0.0576	1838	2476[1]	1235[1]
Error (a)	1	0.0105	0.0189	0.0057	2818	7	10
Protein levels	3	0.0023	0.0106	0.0396	254	428	629
Aureomycin x protein	3	0.0022	0.0026	0.0584	346	147	398
Error (b)	6	0.0065	0.0050	0.0176	130	62	415
Total	15	0.0053	0.0160	0.4676	522	318	471

[1] Significant at P = .05 or less.

Table B (Continued)

Sources of variation	Degrees of Freedom	Initial to 200 lbs. Daily gain M. S.[2]	Feed/100 lbs. gain M. S.	Protein/100 lbs. gain M. S.	Daily feed to 75 lbs. M. S.	75 to 150 lbs. M. S.	150 to 200 lbs. M. S.
Replications	1	--	380	7.16	0.2121	0.0023	0.0559
Antibiotic	1	0.05448	2025	42.58	0.0977	0.2581	0.2761
Error (a)	1	0.00324	420	7.15	0.1425	0.1138	0.1525
Protein levels							
No antibiotic	3	0.00703	64	377.88	0.0882	0.0093	0.4470
Linear component	1	0.000094					
Quadratic component	1	0.01524 [1]					
Cubic component	1	0.00578					
Antibiotic	3	0.00013	102	3.98	0.0319	0.0515	0.6476
Linear component	1	0.00011					
Quadratic component	1	0.00002					
Cubic component	1	0.00026					
Error (b)	6	0.00125	49	1.16	0.0537	0.0700	0.1918
Total	15	--	241	80.63	0.0757	0.0651	0.3279

[2] Mean Square.

Table C. Summary of averages from Experiment 536. [1]

Protein level		10	12	14	16	18	20	10	12	14	16	18	20
		Average daily gains (lbs.)						Average feed/100 pounds gain (lbs.)					
		Initial to 75 lbs.											
Rep. 1	No aureomycin	1.05	1.18	1.28	1.31	1.44	1.21	333	298	316	418	349	306
	Aureomycin	1.00	1.48	1.48	1.46	1.24	1.32	312	259	295	237	330	279
	Terramycin	1.14	1.35	1.47	1.22	1.46	1.54	233	289	294	369	374	248
Rep. 2	No aureomycin	1.00	1.04	1.46	1.34	1.23	1.31	365	331	303	348	337	287
	Aureomycin	1.02	1.23	1.18	1.36	1.33	1.36	346	365	323	317	313	363
	Terramycin	1.16	1.28	1.57	1.43	1.38	1.53	368	364	239	322	356	342
	Average	1.06	1.26	1.41	1.35	1.35	1.38	326	318	295	335	343	304
		Initial to 200 lbs.											
Rep. 1	No aureomycin	1.57	1.63	1.59	1.56	1.73	1.58	374	353	425	371	380	414
	Aureomycin	1.50	1.73	1.83	1.68	1.59	1.58	379	345	333	384	399	372
	Terramycin	1.51	1.74	1.67	1.46	1.65	1.65	391	392	381	401	405	382
Rep. 2	No aureomycin	1.32	1.50	1.62	1.72	1.62	1.67	405	358	416	368	385	359
	Aureomycin	1.37	1.53	1.64	1.71	1.60	1.62	408	377	344	315	353	348
	Terramycin	1.53	1.62	1.87	1.67	1.67	1.58	393	334	331	349	360	375
	Average	1.47	1.62	1.70	1.63	1.63	1.61	392	360	372	365	380	375

[1] Four pigs started per lot, total 144. 129 finished.

Table D. Analyses of variance. Experiment 536.

Sources of variation	Degrees of Freedom	Initial to 75 lbs. Daily gain Mean Square	Initial to 75 lbs. Feed efficiency Mean Square	Initial to 200 lbs. Daily gain Mean Square
Replication	1	0.0049	5625	0.0042
Antibiotics	2	0.0603	1448	0.0054
Nil vs. antibiotics	1	0.0729[1]		0.0084
Aureomycin vs. terramycin	1	0.0477[1]		0.0024
Protein levels	5	0.0971[1]	2023	0.0372[1]
Linear component	1	0.2746[1]	4	0.0442[1]
Quadratic component	1	0.1495[1]	64	0.1054[1]
Remainder	3	0.0615	10046	0.0365
Antibiotic x protein levels	10	0.0121	1646	0.0066
Experimental error[2]	17	0.0099	1812	0.0093
Total	35			

[1] Significant at P = .05 or less.

[2] Since the slaughter data presented came from two replicates which were of different breeds of hog, actually there is some question as to the validity of the interaction of replication x treatment for the estimate of experimental error. In an effort to see if there was an indication of lack of consistency in the response of the two breeds, the responses for the several characteristics under study were plotted over the five protein levels used. A typical plot is presented in Figure 7 and it can be seen that the response of the two breeds, while not identical, do parallel each other. The same relative picture holds for all measurements.

In view of these consistent results, the replication x treatment mean square has been accepted as a reasonably valid estimate of experimental error.

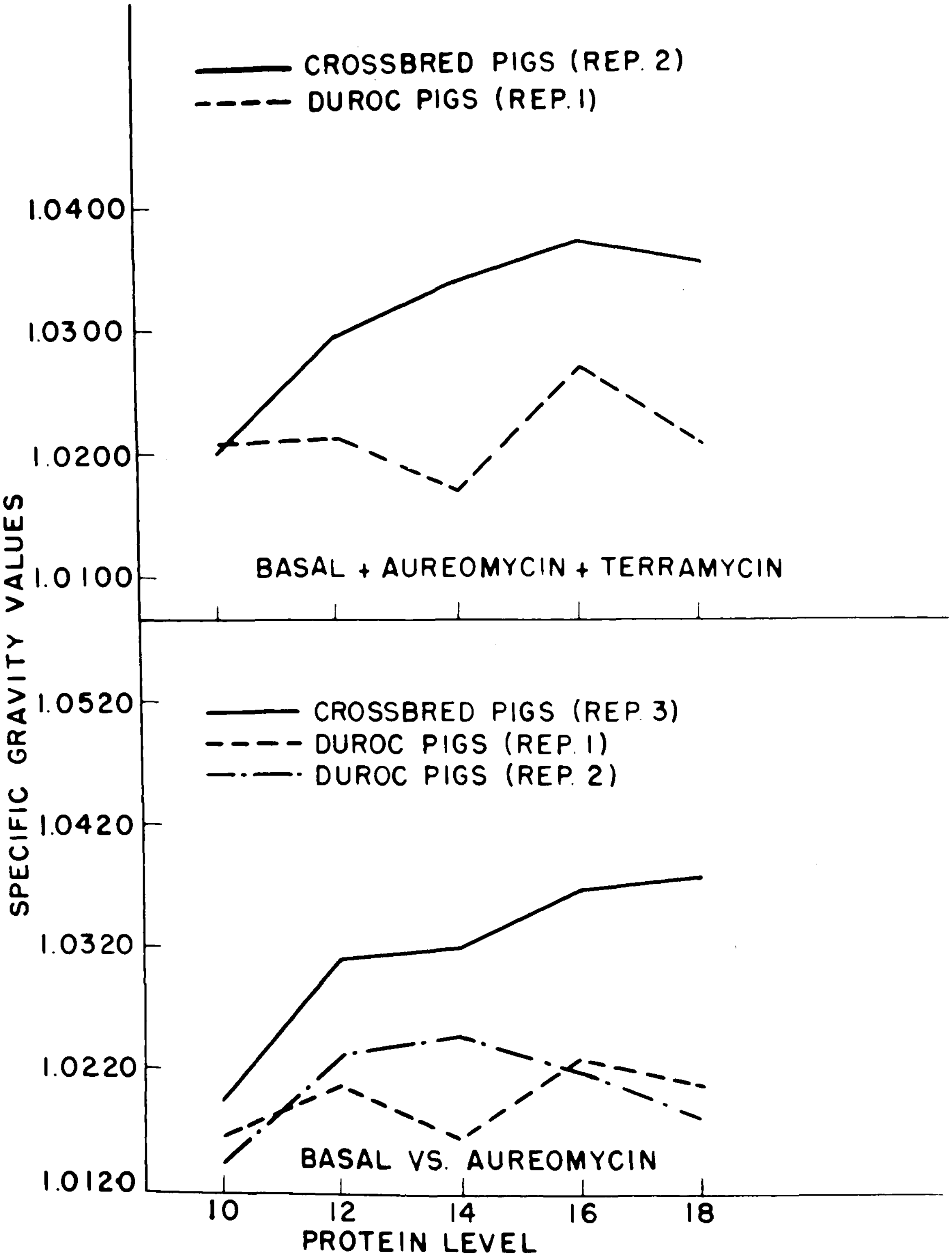

Fig. 7 Breed differences in response to treatment.

Table E. Summary of averages of slaughter data from Experiment 536. 1/

	Protein level 10	12	14	16	18	Ave.
			Back-fat depth (inches)			
Rep. 1						
No antibiotic	1.86	1.66	1.86	1.46	1.87	1.74
Aureomycin	1.66	1.66	1.64	1.63	1.57	1.63
Terramycin	1.40	1.76	1.92	1.54	1.75	1.67
Rep. 2						
No antibiotic	1.46	1.28	1.40	1.42	1.32	1.38
Aureomycin	1.66	1.26	1.38	1.35	1.25	1.38
Terramycin	1.76	1.57	1.40	1.32	1.46	1.50
Average	1.63	1.53	1.60	1.45	1.54	
			Leaf fat (lbs.)			
Rep. 1						
No antibiotic	4.1	5.4	4.5	5.3	4.6	4.8
Aureomycin	4.5	4.6	4.4	5.5	3.2	4.4
Terramycin	4.2	4.0	3.8	4.4	3.6	4.0
Rep. 2						
No antibiotic	4.9	4.5	4.8	4.5	4.0	4.5
Aureomycin	4.3	3.7	4.4	3.1	3.7	3.8
Terramycin	5.4	5.7	3.0	4.0	3.4	4.3
Average	4.6	4.6	4.1	4.5	3.7	
			Percent lean cuts			
Rep. 1						
No antibiotic	56.0	58.8	57.0	58.3	56.6	57.3
Aureomycin	54.6	54.1	60.8	58.2	59.7	57.5
Terramycin	59.8	52.9	56.2	62.7	56.6	57.6
Rep. 2						
No antibiotic	58.1	59.1	64.5	58.7	64.4	61.0
Aureomycin	61.0	64.4	60.8	64.3	58.7	61.8
Terramycin	60.2	60.3	59.0	63.4	57.8	60.1
Average	58.3	58.3	59.7	60.9	59.0	

1/ Each figure represents the respective measurement on one carcass.

Table E (Continued)

	Protein level 10	12	14	16	18	
	Specific gravity values					Ave.
Rep. 1 (Duroc pigs)						
No antibiotic	1.0164	1.0225	1.0166	1.0259	1.0170	1.0197
Aureomycin	1.0180	1.0197	1.0171	1.0211	1.0257	1.0203
Terramycin	1.0283	1.0224	1.0176	1.0330	1.0193	1.0241
Rep. 2 (Crossbred pigs)						
No antibiotic	1.0171	1.0274	1.0322	1.0345	1.0393	1.0301
Aureomycin	1.0222	1.0347	1.0318	1.0376	1.0353	1.0323
Terramycin	1.0208	1.0261	1.0387	1.0407	1.0305	1.0313
Average	1.0205	1.0255	1.0257	1.0321	1.0278	
Rep. 3 (Duroc pigs)						
No antibiotic	1.0159	1.0169	1.0281	1.0198	1.0182	1.0198
Aureomycin	1.0123	1.0296	1.0197	1.0239	1.0192	1.0209
	Carcass length (inches)					
Rep. 1						
No antibiotic	27.6	28.7	28.7	28.5	28.0	28.3
Aureomycin	28.5	28.1	28.4	28.4	28.8	28.5
Terramycin	28.7	28.4	29.2	28.6	27.0	28.4
Rep. 2						
No antibiotic	27.8	28.6	28.2	29.7	29.3	28.7
Aureomycin	28.6	29.6	29.3	29.3	29.4	29.3
Terramycin	29.4	29.3	29.6	30.3	29.9	29.7
Average	28.3	28.8	28.9	29.1	28.7	

Table E (Continued)

	Protein level 10	12	14	16	18	
	Live probe (inches)					Ave.
Rep. 1						
No antibiotic	1.80	1.59	1.75	1.48	1.79	1.68
Aureomycin	1.42	1.75	1.59	1.57	1.63	1.59
Terramycin	1.38	1.78	1.86	1.70	1.89	1.72
Rep. 2						
No antibiotic	1.55	1.21	1.28	1.34	1.18	1.31
Aureomycin	1.50	1.15	1.46	1.34	1.25	1.34
Terramycin	1.59	1.46	1.38	1.36	1.49	1.46
Average	1.54	1.49	1.55	1.46	1.54	
	Area of loin muscle (traced) (sq. ins.)					
Rep. 1						
No antibiotic	3.4	4.3	2.9	3.9	3.9	3.7
Aureomycin	3.4	3.3	3.2	2.7	3.3	3.2
Terramycin	4.3	2.8	3.4	3.8	4.4	3.7
Rep. 2						
No antibiotic	4.2	4.4	5.6	4.2	4.6	4.6
Aureomycin	4.1	4.6	4.2	4.7	3.2	4.2
Terramycin	3.9	4.5	4.3	5.1	3.8	4.3
Average	3.9	4.0	3.9	4.1	3.9	

Table F. Analyses of variance of slaughter data. Experiment 536.

Sources of variation	Degrees of Freedom	Leaf fat M. S.[1]	Percent lean cuts M. S.	Area of loin muscle M. S.	Specific gravity M. S.	Back-fat thickness M. S.	Live probes M. S.	Carcass length M. S.
Replications	1	0.2430	0.920	20.7500	0.000733	8.4535	5.0113	20.33600[2]
Rations	14				0.000044			
Antibiotics	2	0.8845	1.530	0.7600	0.000020	0.2996	0.2592	2.74850
Protein levels	4	0.8176	7.548	2.4800	0.000107	0.4596	0.1030	1.53980
Linear component	1				0.000275[2]			
Remainder	3				0.000153			
Antibiotic x protein	8	0.1237	7.532	0.7738	0.000147	0.2177	0.1338	1.16390
Experimental error	13	0.6500	14.225	1.9758	0.000041	0.4648	0.2472	1.43350
Total	28	0.5258	9.978	2.0877	0.000064	0.6670	0.3696	0.03138

[1] Mean Square.

[2] Significant at P = .05 or less.

Table G. Individual daily gains (lbs.). Experiment 544.

% protein	10				12			
% lysine	.460 0	.480 ¼	.500 ½	.550 1	.630 0	.638 ¼	.645 ½	.660 1
Replicates								
1	1.00	0.78	0.95	0.80	1.20	0.95	0.73	1.20
2	0.92[1]	0.96	0.91	0.67	0.66	0.67	0.88	1.07
3	0.98	0.81	1.05	0.80	1.04[1]	0.97[1]	1.06	1.12
4	0.80	1.03	1.00	1.08	0.98	1.11	1.09	1.11
	(.925)[2]	(.895)	(.977)	(.837)	(.97)	(.925)	(.937)	(1.12)
5	0.96	1.04	0.86	1.00	1.10	1.10	1.12	1.18
6	0.86	0.92[1]	1.02	0.87	1.26	1.04	0.88	0.93
	(.91)[3]	(.98)	(.94)	(.94)	(1.18)	(1.07)	(1.00)	(1.05)
Average	0.92	0.92	0.96	0.87	1.04	0.97	0.96	1.10

1/ Calculated values.
2/ Figures in parenthesis represent gains of first four replicates.
3/ Figures in parenthesis represent gains of last two replicates.

Table H. Individual daily feed (lbs.). Experiment 544.

% protein	10				12			
% l-lysine	.460 0	.480 ¼	.500 ½	.550 1	.630 0	.638 ¼	.645 ½	.660 1
Replicates								
1	3.62	3.09	3.72	3.02	3.91	3.41	2.80	3.97
2	3.22[1]	3.22	2.98	2.57	2.61	2.59	3.08	3.36
3	3.17	2.89	3.48	3.21	3.25[1]	3.06[1]	3.50	3.18
4	3.02	3.44	3.34	3.46	3.17	3.54	3.17	3.66
	(3.26)[2]	(3.16)	(3.38)	(3.06)	(3.23)	(3.15)	(3.14)	(3.54)
5	3.30	3.08	2.89	3.20	3.10	2.88	3.24	3.08
6	3.00	3.14[1]	3.24	2.83	3.50	2.86	2.53	2.68
	(3.15)[3]	(3.11)	(3.07)	(3.01)	(3.30)	(2.87)	(2.89)	(2.88)
Average	3.22	3.14	3.27	3.05	3.26	3.06	3.05	3.32

1/ Calculated values.

2/ Figures in parenthesis represent average daily feed for first four replicates.

3/ Figures in parenthesis represent average daily feed for last two replicates.

Table I. Pounds of feed per hundred pounds of gain. Experiment 544.

% protein	10				12			
% l-lysine	.460	.480	.500	.550	.630	.638	.645	.660
	0	¼	½	1	0	¼	½	1
Replicates								
1	362	396	391	377	325	359	383	331
2	350[1/]	335	327	383	395	386	350	314
3	323	357	331	401	312[1/]	315[1/]	333	284
4	377	334	334	320	323	319	291	330
	(353)[2/]	(355)	(346)	(370)	(339)	(345)	(339)	(315)
5	345	296	336	330	282	262	289	261
6	349	341[1/]	318	325	278	275	287	288
	(347)[3/]	(318)	(327)	(322)	(280)	(268)	(288)	(275)
Average	351	343	339	354	319	319	322	301

[1/] Calculated values.

[2/] Figures in parenthesis represent average pounds of feed per 100 pounds of gain for the first four replicates.

[3/] Figures in parenthesis represent average pounds of feed per 100 pounds of gain for the last two replicates.

Table J. Analyses of variance. Experiment 544.

Sources of variation	Degrees of Freedom	Daily gain Mean Square	Daily feed Mean Square
Replications	5	0.0405	0.3202
Treatments	7	0.0318	0.0738
Protein level	1	0.1170[1/]	0.0000
Lysine level	3	0.0036	0.0397
Protein x lysine	3	0.0316	0.1326
Experimental error	31	0.0175	0.0966
Total	43		

[1/] Significant at P = .05 or less.

Table K. Individual daily gains (lbs.). Experiment 553.

% protein	10				12			
% l-lysine	.447 0	.474 ¼	.502 ½	.557 1	.611 0	.628 ¼	.645 ½	.680 1
Antibiotic								
No aureomycin								
	0.98	0.78	0.84	0.85	1.19	1.13	1.20	1.11
	1.06	0.89	0.77	0.83	1.02	1.30	1.06	1.29
	0.88[1]	0.73[1]	0.69	0.78	1.02	0.92	1.14	1.26
	0.86	0.75[1]	0.70	0.66	1.04	1.20	1.33	1.17
	0.87[1]	0.71[1]	0.86	0.70[1]	1.02	1.08	1.04	1.08
Aureomycin (10 mg./lb.)								
	0.80	0.89	1.04	1.09	1.02	1.26	0.97	1.08
	1.02	0.94	0.87	0.94	1.16	1.19	1.31	1.37
	0.67	0.70	0.61	0.89	1.04	1.15	0.98	1.17
	0.78	0.70	0.80	0.64	1.00	0.98	1.28	1.13
	0.89	0.83	0.78	0.86	0.74	1.00	0.81	1.17
Average	0.88	0.79	0.80	0.82	1.03	1.12	1.11	1.18

[1] Calculated values.

Table L. Individual daily feed. Experiment 553.

% protein	10				12			
% l-lysine	.447	.474	.502	.557	.611	.628	.645	.680
	0	¼	½	1	0	¼	½	1
Antibiotic								
No aureomycin								
	2.95	2.52	2.64	2.59	3.43	3.02	3.18	3.00
	3.37	3.05	2.26	2.87	2.68	3.48	2.78	3.21
	2.89[1]	2.53[1]	2.48	2.76	2.80	2.33	3.12	3.05
	3.00	2.71[1]	2.39	2.83	2.71	3.39	3.00	3.05
	2.87[1]	2.47[1]	2.76	2.56[1]	2.88	2.97	2.96	2.82
Aureomycin (10 mg./lb.)								
	2.46	2.68	3.00	2.96	2.86	3.21	2.61	2.83
	3.15	3.16	2.85	2.85	3.20	2.98	3.37	3.34
	2.63	2.68	2.21	2.38	2.65	3.20	2.55	2.85
	2.84	2.70	2.68	2.65	2.88	2.80	3.41	2.89
	2.75	2.84	2.48	2.66	2.21	2.72	2.63	2.95
Average	2.89	2.73	2.58	2.71	2.83	3.01	2.96	3.00

[1] Calculated values.

Table M. Pounds feed per hundred pounds of gain. Experiment 553.

% protein	10				12			
% l-lysine	.447	.474	.502	.557	.611	.628	.645	.680
	0	¼	½	1	0	¼	½	1
Antibiotic								
No aureomycin								
	300	322	316	306	288	267	265	270
	317	343	294	348	263	267	261	250
	328 1/	347 1/	360	355	271	254	273	243
	350	361 1/	341	427	261	284	225	261
	330 1/	348 1/	321	365 1/	282	276	284	260
Aureomycin								
	306	300	288	271	281	256	270	262
	309	337	328	302	277	250	256	244
	391	384	365	266	254	277	260	243
	365	385	333	416	288	285	266	256
	308	344	318	310	298	272	326	253
Average	330	347	326	337	276	269	269	254

1/ Calculated values.

Table N. Analyses of variance. Experiment 553.

Sources of variation	Degrees of Freedom	Daily gain Mean Square
Replications	4	.0773
Protein levels	1	1.6474[1/]
10% protein		
Antibiotic	1	0.0076
Lysine levels	3	0.0168
Linear component	1	0.0139
Quadratic component	1	0.0342
Cubic component	1	0.0024
Antibiotic x lysine	3	0.0207
12% protein		
Antibiotic	1	0.0156
Lysine levels	3	0.0423[1/]
Linear component	1	0.1081[1/]
Quadratic component	1	0.0015
Cubic component	1	0.0171
Antibiotic x lysine	3	0.0044
Experimental error	55	0.0125
Total	74	

Sources of variation	Degrees of Freedom	Daily feed Mean Square	Feed/100 lbs. gain Mean Square
Replications	4	0.3054	2858
Protein levels	1	0.9879[1/]	92548[1/]
Antibiotic	1	0.0324	99
Protein x antibiotic	1	0.0419	589
Lysine levels	3	0.0457	649
Protein x lysine	3	0.1904	1039
Antibiotic x lysine	3	0.0599	1317
Protein x antibiotic x lysine	3	0.0327	655
Experimental error	55	0.0631	708
Total	74		

[1/] Significant at P = .05 or less.

Table O. Biological values from pigs fed 12 percent protein. Experiment 553.

Sources of variation	Degrees of Freedom	Mean Square	Lysine levels	Type of feeding: Limited		Ad libitum	
				No aureo-mycin	Aureomycin	No aureo-mycin	Aureomycin
			%				
Replication	4	26.4550		61.2	61.2	67.6	65.5
				61.8	67.9	66.2	63.4
Antibiotic (A)	1	1.8300	.611	62.6	59.5	67.3	62.4
				59.4	76.9	62.4	68.2
Lysine levels (B)	3	97.1367		57.9	66.4[2]	65.9	64.9
Antibiotic x lysine levels	3	79.3933		63.5	56.3	69.0	57.8
				59.5	67.4	63.8	57.3
			.628	56.1	65.2	69.4	66.9
Error (a)	28	33.6586		58.1	58.3	60.7	44.5
				63.2	62.6	68.0	59.9
Types of feeding (C)	1	156.5200[1]		62.2	64.7	70.9	67.9
				66.6	67.5	68.7	71.8
Types x antibiotic	1	59.6900	.645	63.7	77.2	49.6	76.4
				62.7	50.0	64.3	72.0
Types x lysine levels	3	19.7767		59.1	58.8	67.2	77.2
Types x antibiotic x lysine levels	3	83.3930		67.0	64.6	69.9	58.9
				67.2	64.9	71.7	68.3
			.680	61.8	54.8	74.1	65.4[2]
				61.8	67.0	67.0	66.2
Error (b)	28	24.3311		65.8	70.6	68.0	68.3
Total	75						

[1] Significant at P = .05 or less.
[2] Calculated values.